

THE CHALLENGES AFFECTING HEAVY LIFT AIRCRAFT
DEVELOPMENT TO SUPPORT SEA BASING

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ABSTRACT

THE CHALLENGES AFFECTING HEAVY LIFT AIRCRAFT DEVELOPMENT TO SUPPORT SEA BASING, by Major Kevin Dean Glathar, 129 pages.

This thesis examines several successful and unsuccessful military aircraft development programs intended to serve as a basis for identifying the potential challenges that might be encountered by developers of heavy lift aircraft required to support the sea basing concept.

In the wake of 11 September 2001, the U.S. armed services began adapting to meet the challenges of a changing global environment. An enhanced sea basing capability is one solution. The sea basing concept is focused on eliminating traditional nodes required ashore to support operational maneuver from the sea. An enhanced sea basing capability is laden with several issues that must be addressed before it can be developed, especially development of new maritime aviation assets.

In August 2003, the Department of Defense directed Defense Science Board Task Force on Sea Basing identifies twelve “dirty dozen” issues, three of which are critical. Development of a heavy lift aircraft capability to support sea basing is one of those three critical issues.

The conclusions reached in this thesis are that design approach, funding, organization, silver bullet theory, vision, technology, and politics are the most prevalent factors, amongst many, that could potentially effect timely development of heavy lift aircraft to support sea basing.

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ACRONYMS

| | |
|--------|---|
| 4ID | 4th Infantry Division |
| AAAV | Advanced amphibious assault vehicle |
| AMC | Air Mobility Command |
| AMIDD | Aviation Maintenance Integrated Diagnostics Demonstration |
| ASE | Aircraft Survivability Equipment |
| ASPG | Army Strategic Planning Guidance |
| ATV | All-Terrain Vehicle |
| CBA | Capabilities Based Assessment |
| CNO | Chief of Naval Operations |
| CONOPS | Concept of Operations |
| CONUS | Continental United States |
| CSG | Carrier Strike Group |
| DOD | Department of Defense |
| DSB | Defense Science Board |
| ERS | En Route System |
| EMW | Expeditionary Maneuver Warfare |
| ESG | Expeditionary Strike Group |
| GAO | Government Accounting Office |
| HLA | Heavy Lift Aircraft |
| HQMC | Headquarters Marine Corps |
| ICH | Improved Cargo Helicopter |
| ISB | Intermediate Staging Base |
| JFCOM | Joint Forces Command |

| | |
|-------|---|
| JIC | Joint Integrating Concept |
| JROC | Joint Requirements Oversight Council |
| JSF | Joint Strike Fighter |
| LCAC | Landing craft, air-cushioned |
| LOTS | Logistics over the shore |
| MCCDC | Marine Corps Combat Development Command |
| MEB | Marine Expeditionary Brigade |
| MEF | Marine Expeditionary Force |
| MEU | Marine Expeditionary Unit |
| MPG | Maritime Pre-positioning Group |
| MCCDC | Marine Corps Combat Development Command |
| NCP | Naval Capability Pillars |
| NSS | National Security Strategy |
| NWDC | Naval Warfare Development Center |
| OEF | Operation Enduring Freedom |
| OIF | Operation Iraqi Freedom |
| OMFTS | Operational Maneuver From The Sea |
| OTS | Off the Shelf |
| QDR | Quadrennial Defense Review |
| R&D | Research and Development |
| RCC | Regional Component Commander |
| RMA | Revolution in Military Affairs |
| S&T | Science and Technology |
| SBA | Simulation-based acquisition |
| SJFHQ | Standing Joint Force Headquarters |

| | |
|---------|-------------------------------------|
| STOM | Ship to Objective Maneuver |
| USEUCOM | US European Command |
| USJFCOM | US Joint Forces Command |
| VLS | Vertical launch system |
| WIDT | Warfare Innovation Development Team |

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CHAPTER 1

INTRODUCTION

Forcible entry from the sea has played an essential role in virtually every major U.S. Military operation, from the “shores of Tripoli,” to the Mexican War, the Civil War, the Spanish American War, World War II and the Korean War. Sea-based operations, practiced by both the Army and Marines, have undergone continuous evolution, culminating in the amphibious assaults that played a decisive role in the European and Pacific theaters in World War II and in Korea. The geography of the United States, as an island power with the need to project military power across two great oceans, has made amphibious warfare a core competence in the American way of war. (2003, iii)

Schneider, *Final Report of the Defense Science Board Task Force on Sea Basing*

Marine Corps Concepts and Programs 2004 states that the Navy and Marine Corps exist to control the seas, assure access, and project power beyond the sea to influence events ashore. It also states that amphibious warfare has become a core competency in the American way of war. Thus, amphibious warfare is critically linked to the United States’ ability to protect its global interests and at the same time fulfill its role as a global power. The Department of Defense (DOD) has determined that sea basing is the capability that will take amphibious warfare to the next level. The intent of amphibious warfare transformation is to yield a more agile force on the battlefield and not be tied directly to cumbersome logistical nodes ashore and still accomplish the mission. In addition to the overarching sea base capability come many subordinate capabilities. The topic area for this thesis is the subordinate capability of long-range heavy lift aircraft (HLA) required to transport and support troops ashore from the sea base (Schneider 2003, ix). More narrowly, the focus is to examine the time required to develop HLA to support sea basing.

The purpose of this chapter is to introduce and restrict the thesis topic. To create a solid foundation, it will contain a discussion on background information, scope, and the importance of sea basing. Included is a discussion on aircraft development from a historical perspective to establish a basis for answering the primary thesis question of whether or not HLA development will keep pace with the overarching sea base concept development. Also discussed will be a number of secondary questions. Lastly, this chapter will address some administrative items surrounding the research of this topic to include the definition of key terms, underlying assumptions, limitations, delimitations, anticipated problems, and if possible, likely solutions.

Background

As a background for this thesis, an overview of the sea basing concept is required to establish relevance to the primary question of aircraft development. In reality, the idea of sea basing is not new. The current development of what is being called “sea basing” is an adaptation to already existing equipment and personnel to meet the changing faces of the enemy and the battlefield on which he chooses to wage war. In the 28 October 2004 draft copy of the “Seabasing Joint Integrating Concept (JIC),” sea basing is defined as: “Seabasing is the rapid deployment, assembly, command, projection, reconstitution, and re-employment of joint combat power from the sea, while providing continuous support, sustainment, and force protection to select expeditionary joint forces without reliance on land bases within the JOA. These capabilities expand operational maneuver options, and facilitate assured access and entry from the sea” (2004, 7). Before discussing the current sea basing concept, history provides some precedent for future sea base development.

In the winter of 335 B.C., Alexander the Great dealt with organizing his kingdom. He concluded that before he could optimally organize his country he would first have to defeat King Darius of Persia and his fleet of 400 warships. This fleet of ships afforded the Persians a tremendous advantage, “which controlled the coasts of Asia Minor, Syria, and Egypt, and was able to deny access to any enemy who did not have equal naval forces” (Tzahos 2004). A couple of more recent examples are Operation Torch, conducted during WWII in Northern Africa, and Operation Chromite, the landing at Inchon during the Korean War.

In late 1942, the Allies opened a second front in North Africa to reverse the assault of the eastern Axis armies. The effort, known as Operation Torch, required a tremendous naval effort. The plan called for a force of approximately 9,000 allied forces to land at Port Lyautry, north of Casablanca, to seize an airport. Simultaneously, 18,000 troops with 80 tanks would land at Fedala and march on Casablanca from the north. A third force of 6,000 with one hundred heavy tanks would land at Safi and advance from the south on the city (Morison 2001). This complex amphibious landing required a sea base of immense size and complexity. Without a well-developed sea base, planners could not insert sufficient combat power to establish a lodgment on Africa’s northern coast.

On 15 September 1950 more than 320 warships including 4 aircraft carriers inserted nearly 70,000 men of X Corps and elements of the 1st Marine Division 100 miles behind enemy lines at Inchon, Korea (Kortegaard 2005). The complexity of this landing was enormous given other factors, like tides, weather, sea maneuver space, logistical considerations, command and control, fire support, and numerous other elements that required a tremendous planning effort to ensure success. However, without

this landing, the Korean War may have had an entirely different outcome. Operation Chromite is another historical example of how important the use of a sea base can be to decrease the limitations imposed by the terrain and the enemy. These are only three examples from history. Others, such as Gallipoli, Normandy, Guadalcanal, Falkland Islands, Desert Storm, and Iraqi Freedom, serve as examples of the importance of a robust sea base for projecting America's military force. Appendices D and E of the *Final Report of the Defense Science Board Task Force on Sea Basing* include more historical background information on sea basing (Schneider 2003, 111 and 135). If history is any indication of how important sea basing has been in the past, then it is no surprise that today's military leaders are placing emphasis on the transformation of the nation's naval capabilities in the form of sea bases to fight future wars.

Since 1992, the naval services have been involved in a major effort to shape their capabilities into a relevant force for the future. The following is an extract from the 1994 Navy-Marine Corps paper "Forward...From the Sea," updating and expanding the strategic concept discussed in 1992.

In 1992 the Navy-Marine Corps paper . . . *From The Sea* defined the strategic concept intended to carry the Naval Service—the Navy and Marine Corps—beyond the Cold War and into the 21st century. It signaled a change in focus and, therefore, in priorities for the Naval Service away from operations on the sea toward power projection and the employment of naval forces from the sea to influence events in the littoral regions of the world—those areas adjacent to the oceans and seas that are within direct control of and vulnerable to the striking power of sea-based forces. The purpose of U.S. naval forces remains to project the power and influence of the nation across the seas to foreign waters and shores in both peace and war. (Dalton 1994, 3)

In November of 2000, the Marine Corps published *Marine Corps Strategy 21* as its capstone strategy to carry the Marine Corps into the twenty-first century. It was drawn

from the strategic guidance contained in the *National Security Strategy*, *National Military Strategy*, *Joint Vision 2020*, and *Forward . . . From The Sea* as depicted in figure 1.



Figure 1. Marine Corps Strategy 21

Source: General J. L. Jones, Commandant U.S. Marine Corps, *Marine Corps Strategy 21* (Washington, D.C.: Department of the Navy, 3 November 2000), 9.

As previously discussed in the introduction to this chapter and in light of the events surrounding 11 September 2001, sea basing has been elevated from a purely naval capability to a national capability applicable to the joint force. As such, each of the U.S. Armed Services' transformation roadmaps and outlines for the 2005 Quadrennial Defense Review (QDR) address sea basing and include plans that support development of this capability. "Sea Base" is just one of the four Naval Capability Pillars (NCP) identified in the *Naval Transformation Roadmap 2003—Assured Access & Power Projection . . .*

From The Sea. Admiral Vern Clark outlines the vision for this change in the “Sea Power 21 Series-Part I” article written for the *Proceedings* magazine.

To realize the opportunities and navigate the challenges ahead, we must have a clear vision of how our Navy will organize, integrate, and transform. "Sea Power 21" is that vision. It will align our efforts, accelerate our progress, and realize the potential of our people. "Sea Power 21" will guide our Navy as we defend our nation and defeat our enemies in the uncertain century before us. (Clark 2002, 32)

Together with information technology to guide the Navy’s transformation and a partnership with the Marine Corps, the four NCPs are: Sea Strike, Sea Shield, Sea Base, and ForceNet (see figure 2).



Figure 2. Sea Power 21

Source: Admiral Vern Clark, USN, *Sea Power 21 Series* (Annapolis, Maryland: U.S. Naval Institute Press, October 2002).

An entirely different geopolitical and military environment is emerging in many areas of the world. The post-Cold War environment has drawn down the size of our military, which has abandoned overseas bases leaving the United States in a compromising position. As a global power, the United States has national interests worldwide and access to some areas with those interests has become increasingly difficult. Operation Enduring Freedom (OEF) was highly dependent on the US's ability to use Pakistan as a base of operations to project power into Afghanistan. Could the US have conducted decisive operations against Al Qaeda and Taliban targets if denied access to both airfields and port facilities in Pakistan? Another recent example of US dependence on foreign bases was Operation Iraqi Freedom (OIF) with denial of access by Turkey to the United States Army's 4th Infantry Division (4ID). This action created a significant cost in time to 4ID by delaying its ability to provide combat power to ground operations in Iraq. Fortunately, combat operations in Iraq were not significantly impacted by Turkey's actions.

Recent history has demonstrated to DOD leadership and other US government officials the importance of sea basing to the nation. Hence, sea basing is the overarching transformational operating concept for projecting and sustaining naval power and selected joint forces.

Scope

The Navy-Marine Corps team is at the forefront of sea base concept development. An article written by John Bennett for *Inside the Pentagon* on 12 August 2004 says that DOD officials have approved a concept development initiative to build a joint capability blueprint that outlines what will be needed to project combat power from the sea. Their

decision is partially based on experiences like that of the aforementioned 4ID situation. Fortunately, units, like the Marine Expeditionary Unit (MEU), have proven that sea basing is a concept that has merit. The MEU provides a forward-deployed self-contained sea base capability of approximately 2,200 Marines and Sailors that can rapidly execute a wide range of missions. However, the MEU capability falls well short of what DOD planners hope to achieve with future sea bases. Arthur K. Cebrowski, the former “Pentagon’s transformation czar,” further describes sea basing in a June 2003 *Sea Power* magazine article titled “Champion of a New American Way of War.” When asked what lies in the future from a Navy perspective he relies,

I can see a whole collection of interesting things happening. The most obvious one is that there is going to be tremendous pressure to improve high-speed lift. That will come in the form of very-high-speed ships and in work on airships--probably, but not necessarily, hybrid airships.

I can see alternative approaches to large multirole ships that don't look anything like current ship designs but that rival aircraft carriers in size. They probably would have high multirole capability and, almost certainly, lower cost. The ships would be reconfigured or would reconfigure themselves. The general approach is that you have a chassis or platform and then you can roll through different capabilities. The excitement isn't in the platform. The excitement is in what it carries. (2003, 15)

Therefore, despite extensive sea base concept development by the Navy-Marine Corps team, significant work remains to be done.

Importance

Based on the background information and the scope of sea basing discussed above, aircraft development is a critical requirement to support the nation’s ability to project power across the globe. In light of current trends to reduce US presence in Europe and Asia, sea basing becomes more critical. The DOD has directed the service chiefs to make some significant changes to support the new national security strategy (NSS). An

indication of the services' response is inclusion of sea basing in the latest strategic guidance for each service. As an example, the *Army Strategic Planning Guidance 2005* (ASPG), addresses the DOD directive as follows:

To ensure our strategic responsiveness, the Army will adjust its goals and processes for mobilization and deployment. The Army must provide rapidly and immediately employable Army forces to the joint warfight. This means moving beyond "breaking" a combat unit at home station, shipping its individual parts, re-assembling it in theater, readying it for combat and then executing the warfight. Department of Defense joint swiftness goals do not allow us time for a lengthy Reception, Staging, Onward Movement and Integration (RSOI) process; therefore, we will adjust Army deployment metrics to ensure they nest within the overarching joint swiftness goals. These revised deployment metrics will guide synchronization and leveraging of existing Army Power Projection Program (AP3) capabilities and concepts with Joint mobility programs and initiatives such as seabasing, strategic lift, enhanced theater access, and Joint deployment training to increase Army strategic responsiveness across the complete range of Joint operations. (13)

Sea basing, as described by the DSB Task Force report, is a critical capability that must be developed in order to provide sovereign territory required to act quickly across the full spectrum of warfare in the future.

Among the dirty dozen issues that are discussed in the DSB Task Force report, three stand out as especially important needs that must be developed: (1) the capability to handle cargo in rough seas, (2) a heavy lift aircraft (HLA), and (3) ships whose design incorporate all the requirements of the sea base system of systems. New ships and rough seas cargo handling may be problematic in the development of sea bases; however, development and procurement of HLA may pose the largest stumbling block to the future sea basing capability. As such, the question of whether or not a new generation of HLA will be ready to support sea basing is one that must be addressed in short order. This thesis will objectively analyze past and present military aircraft development to provide an informed answer to that question.

Aircraft Development

The development of powered flight has been nothing short of amazing since the Wright brothers' maiden flight in December 1903. The numbers and types of different aircraft that have been developed in just over 100 years is a true testament to man's ingenuity. This portion of the introductory chapter will create a backdrop for later examination of past, present, and future aircraft development. The Wright brothers had their fair share of problems when building the Wright Flyer, but the development of aircraft, like the SR-71, B-1B, C-17, and V-22, is a complex and highly delicate matter.

The purpose of the following subsets of aircraft development is to first examine how aircraft development has evolved, focusing on military aircraft development. Next, discuss a number of factors that impact aircraft development.

Evolution of Aircraft Development

Initial aircraft development was primarily driven by man's desire to fly. When the Wright brothers proved powered flight possible, the world would begin to develop aircraft for many reasons. That has changed little today as both civil and military applications for the uses of aircraft are still evolving. Again, the focus of this discussion will be on how the military aircraft development has evolved in the last century. In reality, it is possible to look even further back in military history to see the use of flying machines, like observation balloons used in the late nineteenth century. In the early years of military aircraft development, it was unclear as to what the purpose of aircraft on the battlefield might be. Thus, it was common to see the military purchase aircraft built by civil industry and apply the limited capabilities the aircraft brought to a limited number of missions. As the possibilities of the airplane's use and its capabilities improved, the

military took an interest in the development of its own aircraft that could be developed to fill particular missions, instead of the opposite. This was the moment in military aircraft development where matters became complicated. This would require time, money, and resources not formerly required in the procurement of aircraft. These factors continue to complicate the process of military aircraft development today as those aircraft become more complicated and expensive to buy. To compound the problem, military aircraft developers have to compete for limited resources with other military equipment developers that are equally complicated and expensive. The bottom line is that aircraft development timelines have continued to increase based on the aforementioned factors and many others.

Factors Impacting Aircraft Development

Of all the reasons that aircraft development has become more difficult, none is more prominent than that of funding. Historically, defense spending on aviation has grown disproportionately when compared to other defense programs. This is not surprising based on the many roles that military aircraft fulfill that were formerly done by other means. As an example, the use of modern cargo aircraft to move troops and materials has become more critical than the use of ships for situations that require immediate attention. Another factor that impacts aircraft development, and is directly linked to funding, is research and development (R&D).

Given the historically disproportionate growth in aviation program spending, DOD devotes huge amounts of resources on R&D to develop new aircraft. A study done in 2000 by the Armed Services Committee made it very clear that there will always be hard decisions on what priorities will get funding. “Modernization plans are being

reevaluated, causing DOD to face difficult choices. . . . However, several studies underway could increase mobility requirements, increase number of aircraft DOD wants to buy, and change the extent and timing of aircraft upgrades. Such changes would cause DOD to face difficult choices in deciding how to resolve the shortfalls” (Bateman 2000, 16). The following information from the same report outlines the trend towards much greater aviation program spending.

The total annual funding for operating, maintaining, and buying new airlift and aerial refueling aircraft increased from \$8.95 billion in fiscal year 1988 to \$12.42 billion in fiscal year 1999 (constant 2000 dollars). As a percentage of DOD’s budget, the amount for airlift and aerial refueling has doubled since fiscal year 1988, from 2.3 to 4.6 percent, a small portion when compared to other major military functions such as tactical air forces (over 11 percent) and land forces (over 18 percent). By fiscal year 2005, DOD projects airlift and aerial refueling funding will decrease to \$11.85 billion (4.2 percent of DOD’s budget) because of a decline in the amount budgeted for procurement. Aging aircraft create an additional drain on funding based on the increased requirement for spare parts and resources required to perform depot level maintenance. (Bateman 2000, 9 and 13)

Another reason contributing to this trend of increased spending on aircraft programs is their complexity.

Today’s aircraft have become increasingly complicated, costing much more per copy than their predecessors. Again, the result has been a requirement to spend huge amounts of money on R&D. It is no surprise that within DOD, the competition for those funds is keen. Each service deals with modernization at some point for all of its systems. Thus, tough decisions on spending priorities create complications in R&D. The difficulty for those deciding how much money to spend on aircraft R&D is finding a metric to measure progress. Arguably, a large amount of R&D funding produces minimal results with respect to its use in future aircraft. The fallout from this is twofold: increased funding requirements and more time required to develop the desired system. Ultimately,

this can lead to the cancellation of an entire program. Associated with that are large sunk costs and wasted precious time. Examples of this are the A-12 bomber and more recently the RAH-66 Comanche helicopter. Both programs consumed huge amounts of funds and time in R&D that could have been used elsewhere.

Another factor heavily influencing aircraft development is the vision for employment of new weapon systems. Many assumptions about the tactical employment of these assets are initially drawn up by the warfighter. However, the connection between the warfighter's and engineer's visions of the final platform is lost in the translation. For example, the authors of a RAND Corporation study called *Analysis of Air-Based Mechanization and Vertical Envelopment Concepts and Technologies* argue that what the warfighter envisions as the maximum load capability of the aircraft is vastly different from what aircraft engineers envisioned (Gordon et al. 2001, Chapter 1). Further the study outlined traditional concerns that warfighters have about aircraft survivability; the engineers did not see this as a necessary design consideration. This leads to another series of complicated choices, like dealing with increased aircraft weight, anticipated enemy capabilities, and eventually available funding. Compromises are made and the fallout is either a readjustment to the final number of aircraft to be produced, acceptance of a less capable aircraft, or both.

The aforementioned factors are only a few that affect aircraft development. There are many others more numerous than can be discussed within the scope of this research. The following discussion will focus on some current examples of aircraft that will support sea basing and on factors effecting their development.

Secondary Questions

The first secondary question addressed in this thesis is related to the level of focus on aircraft development to support sea basing: Are the Navy and Marine Corps currently taking steps to meet this critical sea basing shortfall? Initial research indicates that the naval services are exploring aircraft as an answer to a heavy lift capability, as well as other air vessels.

Another secondary question to be addressed relates directly to the question posed in the previous paragraph. Will current aircraft development trends hinder the ability of aviation contractors to produce HLA to support sea basing? This is a difficult question to answer quantitatively given the numerous factors that affect current aircraft development, especially factors like political influences. To ensure that this question is addressed thoroughly; this thesis will examine several past and present military aircraft development programs. This will ensure that current aircraft development trends are put in proper context.

Finally, will funding constraints negatively impact development of heavy lift aircraft? The answer to this question may lie in the analysis of past and present aviation development programs. Additionally, research in the area of past defense budgets and projected trends in defense spending may shed light on the question of sufficient funding. Past political dynamics may also provide evidence that adds validity to an answer concerning funding. History shows that different administrations and congressional dynamics have been more willing than others to open the purse strings to support defense spending. Another avenue that may yield additional funding is foreign partners to help defray costs of HLA development and procurement. The challenge in examining the

funding question will be to ensure that the analysis remains objective.

More of a tertiary question is that of other heavy-lift options to support sea basing. What other airborne heavy lift options are available to sea basing developers should it take too long to develop aircraft to support the heavy-lift requirement that is critical to sea basing? This may not only include aircraft options, but surface vessels. Other options that are currently being explored are dirigibles, lighter-than-air craft, and sea planes. Although these platforms show potential, the focus of this research will be on past and present aviation and surface platform data. There are many pitfalls in examining the aforementioned conceptual programs in this thesis. Most notably is a lack of practical historical usage of these platforms. More importantly, very little developmental data in the form of timelines exists from which to make any assertions about potential timelines to actually develop them.

Key Terms

In defining key terms for this research project, it will be imperative to use the most current terminology that relates to both sea basing and military aircraft development. Initial research has already uncovered the use of different terms not only by sources outside the Navy, but also within. When possible, until a joint standard for terms related to sea basing is released, this research will use key terms that are used by Navy and Marine Corps publications to build continuity throughout the thesis.

Two additional sources for key terms are the *Draft Seabasing Joint Integrating Concept*, “Glossary and Acronyms” (2004, Appendix B), and the *DSB Task Force Sea Basing Report*, “Terms of Reference” (2003, Appendix A). These documents serve as the

latest information guiding sea base development. The next chapter will discuss literature that will be used in the research for this thesis.

CHAPTER 2

LITERATURE REVIEW

Introduction

The purpose of this chapter is to examine research that has already been accomplished about the topics of sea basing and aircraft development. The result of this examination assists in the discovery of some relevant underlying patterns in those works to further refine continued research in support of this thesis. The initial pattern chosen to use as a framework for this chapter is *cause and effect*. This pattern serves as the most effective means of conducting research for topics related to both sea basing and aircraft development. For example, factors that influence development of aircraft stem from many *causal* factors. Some of these factors, such as budgeting and technology, are directly related with aircraft development. While others, such as politics, are more difficult to link directly as causal factors affecting aircraft development but certainly have merit when weighing all possible factors involved. The first portion of this chapter briefly lists and describes the literature required to successfully lay the foundation for an understanding of the latest sea-basing concept. The latter portion of this chapter uses potential factors affecting aircraft development as a framework. Within this framework, a brief discussion will describe which literature is most relevant to each factor and which best supports finding the data required to address the primary research question. Again, sea-basing literature will be discussed first.

A Case for Sea Basing

Tremendous amounts of information on the subject of sea basing are readily available in nearly all forms including both primary and secondary sources. Information on aircraft development to fulfill the critical heavy-lift short fall is not as plentiful and will be discussed later in this chapter. Initial interviews with the lead logistics developer for sea basing at Headquarters Marine Corps (HQMC) in Quantico, Virginia, Mr. Nick Linkowitz, have provided a wealth of primary source information for sea base development. Mr. Linkowitz further recommended contacting Mr. John Peveler at the Naval Warfare Development Center (NWDC) in Newport, Rhode Island. He is the coordinator for the Sea Base Warfare Innovation Development Team (WIDT) in Newport and distributes a biweekly newsletter that provides the latest information on developmental plans for sea basing. The newsletter also provides a list of the latest documents pertaining to sea-base development. This archive of documents is located on a Navy website called the Sea Basing Sharepoint Site. Additionally, this newsletter provides a forum for anyone subscribing to establish liaison with the Sea Base WIDT. Finally, the newsletter tracks all events within DOD that apply to sea-base development. This source proves to be highly in tracking not only sea-base development progress, but also aircraft development to support sea basing.

Currently, the document that provides the latest guidance for sea base development is the draft copy of the *Sea Basing Joint Integrating Concept* version .65 dated 28 October 2004. The lead staffing element for this document is the J9 Directorate at the U.S. Joint Forces Command (USJFCOM). Important to establishing the foundation for this research is gaining an understanding of each of the documents listed in Appendix

A of the *Sea Basing Joint Integrating Concept*. The following is a list of those documents.

National Security Strategy (NSS), September 2002

National Military Strategy (NMS), 2004

Quadrennial Defense Review (QDR), 30 September 2003

CJCSINST 3170.01D, *Joint Capabilities Integration and Development System*

Joint Concept Development and Revision Plan, July 2004

Joint Operations Concept (JOpsC), November 2003

Major Combat Operations Joint Operating Concept (MCO JOC), 24 March 2004

Force Application Functional Concept, February 2003

Focused Logistics Joint Functional Concept, December 2003

Joint Command and Control Functional Concept (draft)

Protection Joint Functional Concept, 31 December 2003

Functional Concept for Battlespace Awareness, 31 December 2003

Defense Science Board (DSB) Task Force on Seabasing, August 2003

NWDC/MCCDC Enhanced Network Seabasing Concept Paper

JFCOM Joint Seabasing Concept of Operations (draft), July 2004

Chief of Naval Operations (N703) Seabasing Concept of Operations (draft), March 2004

Also considered in this research is literature disseminated by the DOD, Office of Force Transformation. This literature includes *Military Transformation*, *Elements of Defense Transformation*, *The Implementation of Network-Centric Warfare*, and the transformation roadmaps for the Army, Air Force, and Navy. This literature is instrumental in building a case for sea basing and describing its importance to the Nation.

The significant shift from Cold War defense strategy to the strengthening of alliances to defeat global terrorism and to prevent the proliferation of weapons of mass destruction is the common theme throughout all the aforementioned documents and makes sea basing a critical transformational capability to support the new strategy.

Again, it is clear that sufficient material is available to support the requirement for the sea-basing research contained in this thesis. The same is not true of material available for aircraft development that supports future sea bases.

Aircraft Development

Throughout the research involved to develop this thesis, no program office for aircraft development in support of sea basing has been formed. The fact that this office does not exist creates unique challenges in collecting research on this topic. Further, Mr. Peveler indicates that ongoing debate in military channels over aircraft development devoted to supporting the overarching concept of sea basing continues to be scarce if not nonexistent. This produces a rather difficult problem to solve in that clear direction from DOD does not exist to establish joint requirements for what aircraft to support sea basing will look like. Albeit, many individual efforts are ongoing and provide conceptual air platforms that could support sea basing. This may prove beneficial, but it is more likely that a tremendous amount of time will have been lost through a disjointed effort in concept development.

The Combined Arms Research Library (CARL) at Fort Leavenworth, Kansas, is a useful repository, whose staff assists with searches for literature to support aircraft development research in a broader context outside support to sea basing. CARL contains numerous official United States government reports and news articles chronicling the

development of other aircraft. That historical record helps developing data for the analysis done later in this thesis. Additionally, the Internet provides an endless wellspring of information in the form of both primary and secondary sources not available in the CARL.

The following is a discussion framed by the potential researchable causal factors that may effect aircraft development. When applicable, literary works that may shed light into validating their significance are mentioned. The initial order of these factors is purely subjective based on the author's perspective before this research. Factors may be added or subtracted later as the research develops. The last chapter of this thesis will assign an order of importance while addressing recommendations for future aircraft development.

Vision and Concept

As previously discussed, there has been no lack of effort on the part of several individual entities, both civil and military, to develop conceptual ideas and models of air platforms that could potentially support sea basing. This is arguably a very positive factor in that when all of these efforts are pulled together, they will have a tremendous amount of ground work done to begin the process of building and testing prototypes. However, one could also argue that this could create potential problems with focus as there are a wide variety of different conceptual platforms on the drawing board: everything from larger conventional helicopters to giant flying wings.

Currently, Navy and Marine Corps developers are advocating large vertical lift platforms similar to capabilities that already exist in the U.S. Naval inventory. Additionally, they are examining the feasibility of using dirigibles, lighter-than-air (LTA)

type craft that would transport personnel and material. A demonstration of this capability was initially tested in the fall of 2004.

Civilian industry has also been very active in the development of concepts for air vehicles that could support sea basing. The focus of those companies has been more of a fixed-wing type craft with some other ideas, like that of a large hover type craft being researched by Bell-Boeing.

The primary reason for this disparity in vision is a lack of understanding of what the aircraft will be required to do. The Navy and the Marine Corps are focused on how they will move personnel and materials from intermediate staging bases to a sea base and then from the sea base to objectives ashore: intratheater lift and ship-to-objective maneuver (STOM), respectively. The civil sector on the other hand envisions aircraft that will move military personnel and cargo from CONUS to a sea base and potentially from ISBs to the sea base; thus a longer view and subsequently more of a focus on fixed-wing aircraft. Given this large disparity, and to best support this research, the literary focus will be on historical aircraft data points.

Historical Aircraft Development

The idea that historical examples provide an effective means of developing this thesis is critical. Given the aforementioned disjointed effort to develop aircraft that support sea basing, history is the best place to start. With the exception of a few very off the chart concepts, most of the conceptual air vessels being looked at to support sea basing are essentially another look at something that has already been developed in the past or an aircraft that was dreamed up before its time. In other words, technology was not available to support some of the failures or rejected ideas of the past. Now that

technology has had time to progress, those ideas can be rekindled. This research will not only examine successful historical aircraft examples, but unsuccessful programs as well. This will provide adequate depth to the analysis portion of this thesis. Resources for both cases are abundant.

Several significant aircraft development programs that are ongoing that will also provide excellent sources of data. Those programs include the V-22 Osprey, F-35 Joint Strike Fighter, and the F-22 Raptor. The fact that they are recent programs makes most of the information relevant to heavy lift aircraft development as that program will encounter similar challenges. Additionally, several of the conceptual aircraft already being discussed for heavy lift aircraft are derivatives of the Osprey; thus, realistic development timelines exist for application to development of heavy lift aircraft. This provides a much better basis to argue for or against the research problem statement. Additionally, it may be worthwhile to explore some options other than aviation such as ships and other surface vessel programs as those platforms may actually become part of the equation should aviation development become cost prohibitive.

Budgeting and Funding

As previously discussed in the introduction to this thesis, funding finds its way either directly or indirectly into the equation when considering aircraft development. The primary focus of research for this factor will be use of Government Accounting Office reports and official records individual services on past expenditures for aircraft development. Lastly, past and projected DOD budgetary information from U.S. Senate website is important to establishing how important aircraft development is to each of the aforementioned organizations.

Organization

The bulk of evidence available for this factor is derived from human contacts as no Joint Program Office exists. The aforementioned points of contact will lend insight on potential lead agencies for aircraft development to support sea basing. The remainder of the research will be focused on historical information about the organizations involved in development of those platforms. Validating the importance of this factor to aircraft development is more difficult in that it deals heavily with the intangible human element. Arguably, it is obvious that this factor does effect aircraft development as demonstrated by the lack of a single office as the lead for the sea basing aircraft. The extent to which this is a detriment is a much more difficult prospect, especially when attempting to determine additional time required to develop an aviation platform. Again the human factor weighs heavily in organization to develop aircraft as is does with the last factor discussed in this chapter, politics.

Politics

This is another difficult factor to quantify when attempting to research its effect on aircraft development timelines. It is difficult to determine the significance of this factor. Politics involve much more than a single human element, but three different political human elements. They are civilian, governmental, and military politics. The best way to approach this challenge is through the use of current periodicals and media outlets to collect data on all three entities. There is also a significant amount of literature written on this topic by credible authors and agencies, for example, *The Pentagon Paradox*, written by James Stevenson. This book tells the developmental story of the F/A-18

Hornet aircraft. It focuses heavily on how politics by each of the aforementioned entities affected the Hornet program.

The previously mentioned programs currently in development will also provide a wealth of current information on how politics is affecting their progress. Each of these programs has potential for cancellation. The V-22 is a perfect example in that it has been down a rocky road throughout its continuing development; politics have almost killed the program several times. Interestingly enough, politics have also saved the program.

Problem Statement Revisited

As the Department of Defense executes a large-scale transformation to meet the challenges of changing global threats, each of its armed service components is looking inward to comply with transformation guidance. This transformation within DOD creates unique challenges for each branch of the Armed Forces. The United States Navy and United States Marine Corps are currently in the midst of many transformational challenges with respect to continued development of future concepts and capabilities. Of those challenges, one critically important development is the Sea Basing concept. This concept represents the integration of the transformational thrust of Marine Corps Strategy 21 and the Navy's Sea Power 21 visions. Recent history has demonstrated to DOD leadership and other U.S. government officials the importance of this capability not only to the Navy and Marine Corps, but to the Nation. It provides a capability that directly supports the second priority in the National Military Strategy, enhancing our ability to fight as a joint force. Hence, sea basing is the overarching transformational operating concept for projecting and sustaining naval power and selected joint forces. According to the August 2003, DSB Task Force on Sea Basing, sea basing will be a critical future joint

military capability for the United States. The Task Force has identified twelve issues that DOD must address in undertaking implementation of a sea basing capability. Of those twelve, three are especially important. Of those three significant issues, the development of heavy lift aircraft (HLA) provides the basis for this thesis. The development of HLA is so critical that without this capability, sea basing may not be possible. More narrowly, this research will focus on aircraft development with respect to timelines that will enable these aircraft to support projected employment of the first sea basing operations.

Primary and Secondary Questions Revisited

Will a new generation of heavy lift aircraft be ready to support Sea Basing? Is the Navy or Marine Corps currently taking steps to meet this critical Sea Basing shortfall? Will current aircraft development trends hinder the ability of aviation contractors to produce heavy lift aircraft? Will funding constraints negatively impact development of heavy lift aircraft?

Conclusion

This chapter has reviewed potential areas of focus for research to develop this thesis. It has also discussed potential literature for use in researching the specific topics of sea basing and aircraft development. This review has shown that literature containing information about sea basing is more than adequate both in quantity and quality. With respect to aircraft development literature, a definite shortfall exists in the form of directives from DOD. However, through the use of both historical aircraft data and information written about current aircraft programs, sufficient literature is available to develop the thesis. Additionally, this review establishes that more than adequate data

exists to support analysis of the subordinate causal factors affecting aircraft development.

The underlying pattern discovered in this review and used as a framework is *cause and effect*. This pattern acts as a basis for the next chapter on research methodology.

CHAPTER 3

RESEARCH METHODOLOGY

Background

The primary question that the research seeks to answer is, Will HLA development keep pace with sea basing development timelines? The basic research design used to answer that question is the case study method of previous aircraft development programs. The key elements influencing aircraft development identified in chapter 2 are used as a means of establishing a similar set of parameters for evaluation in each case study. Those parameters represent a control group of elements that create measurable data for comparison of individual case studies against each other.

The resulting data is then used to determine the extent to which each factor affected previous aircraft development, positively or negatively. The goal is to determine which factors either help or hinder successful development of aircraft with respect to time. This provides a datum with which to compare current development of HLA, as well as other possible aeronautical concepts, that could be used to support sea basing. Again, the focus is on determining the effect on the time required to develop HLA, not capability. The resulting analysis yields an objective answer to not only the primary question, but also the following list of secondary questions: (1) Is the Navy or Marine Corps currently taking steps to meet this critical Sea Basing shortfall in the form of a program manager? (2) Will current aircraft development trends hinder the ability of aviation contractors to produce heavy-lift aircraft? (3) Does the vision meet the requirement? (4) Does historical aircraft development provide a relevant model for future ventures? (5) Will emerging technology support the vision? (6) Will funding constraints

negatively impact development of heavy-lift aircraft? (7) Will a joint enough environment exist amongst services to support HLA development? and (8) How will politics affect HLA development?

Logical Relationships

As previously noted, the literature review discloses several factors that impact aircraft development. This is critical in establishing a means of qualitatively comparing those affects on the time required to develop an aircraft. The logical relationship established is between each of those factors and the primary research question.

One additional logical relationship that is important to establish is the linkage between the historical aircraft development and the HLA example. It is necessary to carefully choose historical examples that represent similar programs to the HLA. For example, comparing a radically new aircraft technological design or a mere modification to an existing mature aircraft design will have negative affects on the data collected from the factors chosen for the case study analysis. The pitfall in overlooking this relationship is possibly drawing false conclusions from how the factors identified actually affect the HLA development program timeline.

Means of Discovering Evidence

Careful consideration in choosing appropriate examples for collection of evidence yields many possible historical aircraft development programs. Arguably the best example for use in this research is the V-22 Osprey. At this time, the Osprey program has not entered full rate production (FRP); however, barring similar setbacks that the program has already experienced the United States Marine Corps will be deploying the

first squadron of Ospreys in a couple years. The most important reason for analyzing the Osprey programs is that it represents the closest example to what the HLA program may embody with respect to capabilities. Additionally, the program represents the first extensive use of computer modeling in development of the aircraft not unlike what the HLA program will use in the initial stages of aircraft development. Lastly, the Osprey program contains examples of both success and failure caused by a number of factors that are represented in the control group chosen in this research.

The next example examined is the C-17 Globemaster III. This program provides another example that represents HLA development in that system specifications imposed a demanding set of reliability and maintainability requirements. The C-17 also represents a relatively modern example of aircraft development; thus, data collected is more representative of the affects on the HLA program. The most important aspect of the C-17 case study is the huge success this program represents. Based on the similar development conditions that the HLA may experience, this provides a best-case timeline example for comparison to future HLA development. In stark contrast is the A-12 Avenger II program which represents the largest contract termination in DOD history.

On 7 January 1991, Secretary of Defense Richard Cheney canceled the A-12 program for a myriad of reasons to include most notably the cost of the program. The biggest advantage of using a case study of the Avenger II is its monumental failure. As in the case of the C-17, which represents a best-case timeline scenario, the A-12 represents the other end of the spectrum.

The last case study to be conducted is the F-35 Joint Strike Fighter (JSF) program. This program is much like the Osprey program in that it is not yet in full rate production.

Again, based on the current status and maturity of the program it would be unlikely this program would be cancelled. The most advantageous reason for choosing the JSF is that this program represents the “jointest” program to date. Given the current trend in DOD weapons systems development, the HLA will be no different; thus, the JSF is an excellent choice for evaluation.

Lastly, evidence to date for the HLA development is collected to determine initial progress in the program timeline for comparison to the aforementioned programs. Again, the other good choices that could have been examined are numerous. The intent behind restricting the research to four programs is to create a proper balance between manageability and sufficiency in data that is collected. Too many add unnecessary complexity to the research and too few restrict the amount data that is necessary for validity in the analysis portion of this research.

Ways to Implement the Means

The basic research plan calls for a qualitative approach to the case study research method, but a quantitative approach adds value to each of the aforementioned factors affecting aircraft development. A combination of qualitative and quantitative approaches to a case study research method is not unprecedented and is actually recommended for research on modern systems involving technological topics. This further contributes to the use of the data collected for comparison of the chosen relevant factors to other aeronautical platforms being considered to support Sea Basing.

System to Assess and Record Results

In order to properly record results, it is necessary to create a running log of the results from each historical aircraft program case study. Additionally, to facilitate the aforementioned qualitative and quantitative approach for use in the analysis of the data, it is beneficial to create tables that depict each program on one axis of the table and the factors examined on the other axis. The qualitative table uses a convention of positive and negative remarks to indicate the overall affect the given factor has on aircraft development timelines. This approach will also use remarks to amplify any extenuating circumstances that may render the factor irrelevant.

Quantitatively, it is possible to use the same table set up described in the proceeding paragraph. The difference in the tables is the assignment of a predetermined value scale to each factor. This allows for a running total for each case study that gives a more definitive comparison to the HLA or other aeronautical concepts evaluated. The disadvantage to this is trying to assign value to unrelated factors that are difficult to establish values for.

Use of the case study research method does not lend itself to easily nailing down a definitive answer to how one factor affects the research question in all programs compared to HLA. However, the advantage to this method of assessment is that it allows some room for evaluation of factors, such as politics and jointness, outside the context of just an assigned value. Factors, like those listed, need to be addressed in a manner that examines the intangible qualities associated with them.

Conclusion

The purpose of this chapter is to establish the basis for the research design used as a method of evaluating data required to answer the primary question. Again, the use of a case study approach proves to be the best method of comparing unrelated factors to a single research question. The research data is compiled in both a qualitative and quantitative manner as a means by which the data collected can be assessed in an orderly fashion. Again, the focus of the research is on answering the question, “Will HLA development keep pace with Sea Basing development?”

CHAPTER 4

ANALYSIS

Technology, it seems, can be worshipped, enjoyed, respected, admired--even loved. It may provide job opportunities or reasons for not doing the job. As institutions face the confusion of the modern era, their leaders may find it easier to seek after a new bid of hardware rather than confront underlying problems. It is quite clear that many modern organizations find their attention dominated by gadgetry which by-passes consideration of mission or purpose. While in some cases the technology is appropriate, in others what develops is an inappropriate fixation technology--technomania--with a corresponding technopathology contaminating administrative structures. (1980, 156)

Frederic A. Bergerson, *The Army Gets an Air Force*

Introduction

This chapter analyzes historical and current aircraft development data through a case study approach. Detailed information for each aircraft case study is located in appendices A through I. The goal is to establish qualitative evidence that will enable an objective discussion of conclusions and recommendations, with respect to the primary thesis question, in the next chapter. This evidence will also provide potential answers to the secondary questions stemming from the thesis problem statement.

Again, this chapter draws data from a series of aircraft developmental case studies. The analysis encompasses a wide range of aircraft including both fixed and rotor-wing aircraft programs. These aircraft also represent a sampling of programs with several different missions to ensure a broad perspective from which to make objective conclusions. For the same reason, both successful and troublesome aircraft development programs are examined in order to provide an appropriate perspective.

The metric used to gauge between successful and troublesome programs is based on relative success of the airframes with respect to development timeline and mission fulfillment after fielding. Successful aircraft programs examined are the C-17 Globemaster III, A-10 Thunderbolt, F-16 Fighting Falcon, and AH-64 Apache. The other programs examined have either been cancelled or encountered significant problems in the developmental stages. Those aircraft are the V-22 Osprey, A-12 Avenger II, F-35 Joint Strike Fighter, F-22 Raptor, and RAH-66 Comanche.

The aforementioned aircraft case studies used as data points for this research reveal several prevalent factors that affect aircraft development. Not all of these factors are observed in every case study, but they represent those factors that occur most often when considering the sampling holistically. Therefore, instead of discussing each aircraft case study at length in this chapter, these factors will be used as a framework for synthesizing the research data. Those factors are vision, design approach, technology, funding, politics, organization, and the Silver Bullet theory. This framework will also facilitate a smooth transition to the conclusions and recommendations made in chapter 5.

Developmental Factors Discussion

Vision

With respect to vision and concept, it is clear that programs which found a joint service R&D audience were initially very successful as in the case of the V-22, A-12, F-22, and F-35 programs. Joint development has not only become a trend in recent years, but the standard for turning vision into aircraft. The disturbing observation made from the four aforementioned platforms is that all have met with significant problems and the Avenger II was canceled despite joint interest in the program. If one looks at the more

successful programs such as the C-17, A-10, F-16, and AH-64, it becomes apparent that each of these aircraft was developed to fulfill the need of a single service. The assessment is clear; although initially beneficial with respect to funding and political support, joint concept development has proven to be detrimental in later stages of development. Why is this?

At first, the idea of pooling assets and funds to create a joint platform to fulfill the many roles of each service component involve is noble. However, individual service chief Title 10 responsibilities create a hindrance. As the engineers and aircraft manufacturers attempt to create prototype aircraft that will somewhat meet the vision, it becomes clear that more time and more money will be required to keep the program afloat as best seen in the case of the A-12. Individual services, which are now depending on a platform that meets replacement timelines, and lawmakers, who are watching the rising costs of the program, enter a head to head battle to save and kill the program respectively. The result is a lose-lose situation in which services continue to nurse along aging aircraft fleets and political budget analysts cringe at not only rising R&D costs for an aircraft that may never fly, but added Service Life Extension Programs (SLEP) costs that were not budgeted either. This is definitely the case when examining the V-22 more closely. A program more than 30 years in the running that has left the Marine Corps continually reallocating funds from critical programs to extend the life of its aging C-46E and CH-53D/E fleets. So where does the buck stop?

In the most recent cancellation of an aircraft program, the Comanche is probably the closest answer to that question. The buck does not stop until billions of dollars have already been invested and by the time the decision is made to cut losses, those losses

have cost not only precious budget dollars, but more importantly valuable time that can never be regained. So why the fixation with conceptual aircraft that serve as multirole platforms when one size may not always fit all? What platforms could be used to more efficiently develop future aircraft designs?

Design Approach

The basic premise behind this factor is that revolutionary leaps in capability may not be a viable approach to aircraft development in all cases. The approach to new aircraft design is the critical link between vision and technology. The C-17 is probably the best example of an aircraft that took existing aircraft technology and designs to develop a platform that far exceeded the performance of those same designs. This is not the case in platforms such as the A-12, F-22, RAH-66, and V-22. These aircraft represent programs that called for capabilities far beyond or much different than anything available in the aircraft at the time. Therefore, they all required significant R&D for technology that did not exist, see appendices B, F, H, and I. This is a disturbing trend when one considers the fact that two of those four programs were cancelled. Again, an evolutionary approach to development of new aircraft has merit unless precluded by unprecedented technological advances.

Perhaps the most important observation to take away from this factor is that unless a revolutionary technology comes along to enable the development of such concept aircraft, resources are better invested in evolutionary development of platforms that will provide guaranteed incremental leaps in capabilities vice vague hope for monumental advances.

Technology

The DOD spends enormous sums of money each year on science and technology (S&T) research, most of which yields negative results and many would argue a lost investment. Fiscal year (FY) 2006 requests for sea basing aircraft S&T funding examples include \$206.4 million and \$272 million for its V-22 and heavy lift replacement (HLR) programs respectively (Magnus 2005, 14-5). The Army will spend \$20 million and the Navy and additional \$7 million on joint heavy lift aircraft S&T between FY 2005 and 2007 (Castelli 2005b). These examples are but a small percentage when compared to other S&T funding for programs which amount to several billion dollars in some instances.

Some would argue that these examples represent sunk costs that must be endured to ensure advancement in technologies for future military equipment development. Regardless of which side one takes, the facts remain that this research does yield significant advances in technology that can be applied to many different military applications. With respect to aircraft, most of the radio, navigation, and weapons that current U.S. platforms use were developed through dedicated S&T research funded by the DOD. Military aircraft development has also benefited greatly from the technological advances made by the civilian sector for non-military applications and vice versa. The problem with this technology development is that it does not provide a reliable timeline by which aircraft developers can depend.

In all the aircraft case studies examined, none have married up neatly with the development of a technology that has provided a significant implementation in its design. On the other hand, all that actually made it to full rate production later benefited from the

addition of subsystems that made the aircraft more capable. Probably the best examples of aircraft that actually represent a monumental increase in basic design and capabilities were aircraft that first used the jet engine and helicopters that used Ivor Sikorsky's basic flight control design. Arguably, platforms, like the V-22 and F-22, represent potential giant leaps in capabilities based on use of technology yielded from previous S&T research. This is true, but with the exception of the V-22 revolutionary tilt-rotor design, those capabilities were afterthoughts manifested in aircraft modifications or add-on systems (see appendix I). Again, many will argue for and against the benefits derived from the S&T efforts especially in support of future aircraft design. More importantly, it is an undisputed fact that it is an expensive undertaking.

Funding

Expensive undertaking might be a gross understatement when considering budgetary factors affecting military development programs. Military aircraft development is a multi-billion dollar a year venture that arguably does not yield the bang for the buck. On the other hand, the United States has accomplished more in the realm of aircraft capabilities compared to the rest of the world; this nation is unmatched in military aircraft capabilities across the full spectrum of platforms. Again, the price tag has been enormous and continues to grow.

In 1944 when Henry Ford's Willow Run plant was producing a B-24 Liberator every 63 minutes (Overy 1995, 197), the average cost per aircraft in today's dollars was approximately \$336,000 (The Global Aircraft Organization 2005). The average cost per aircraft produced in World War II, even in today's dollars, is a fraction of what the U.S. spends on aircraft development today. Even the smallest and seemingly inexpensive

aircraft cost millions of dollars a copy, and that is just the initial cost. Many of these aircraft cost tens of thousands a flight hour to operate and many millions more to upgrade. So how does all this affect aircraft development?

It all starts with those who hold the DOD purse strings, Congress. In every aircraft program examined in this chapter, the ability of a service or multiservice aircraft development program to get off the ground was highly dependant on congressional approval. This may sound like an obvious statement given the current legal parameters within which civil and military leaders must operate to conduct R&D and field new military equipment. That is precisely the problem. The current configuration legally hamstring the DOD's ability to somewhat independently develop and buy equipment that is desperately needed without a long and cumbersome process of convincing lawmakers of its importance. This system does have merit, but is more likely to inhibit aircraft development.

Congress has always had control of DOD procurement to one extent or another, but in the recent three or four decades, this strict control has created an environment in which the Armed Services must justify every purchase at the cost of time and more importantly, the services must also comply with a very strict joint focus on aircraft development. That in itself is not bad, but when it leads to a "Silver Bullet" program that is incapable of giving any of the services the capabilities they need to replace aging aircraft, the result is an Avenger II or Comanche that has wasted not only precious budgetary resources, but time, see appendices B and H. These are examples of what is more commonly becoming known as "bow wave" spending. Virginia Congressional

candidate and former Marine, David Ashe, explains the effect of bow wave spending in the Comanche program.

Military spending, like any spending, must be smart and prioritized so that waste does not consume our precious defense dollars. Poor advance planning for long range systems creates a "bow-wave" of unexpected costs that can kill an otherwise excellent program. For example, the Comanche helicopter program, which could have been a valued addition to our tactical inventory, failed after 21 years and 7 billion in spending. (Ashe 2005)

Given that Congress plays a significant role in decisions concerning military spending, it should be no surprise that politics are another significant factor that influences affecting aircraft development.

Politics

This particular factor can be broken down into three separate areas: (1) civilian, (2) governmental, and (3) military politics. Each has a unique influence on the successful or unsuccessful development of aircraft.

Starting with the civilian area, this refers mostly to the contractors and aircraft developers that are in competition for rights to R&D and ultimately build aircraft for DOD. Several trends are prevalent from the aircraft case studies examined in this chapter, especially in those unsuccessful programs examined. The influence of the civilian industry on aircraft developmental timelines is seemingly becoming greater as the cost and complexity of aircraft design increases. Appendix B outlines how A-12 contractors were able to hide behind the lack of current technology development to buy more time and receive more money to continue development of a program that is clearly not going to meet any pre-established timelines. This is understandable in aircraft like the A-12, F-22, and RAH-66 which represent significant leaps in capabilities given current technology

available to support the vision as discussed previously. However, this does not relieve the contractor of the responsibility of painting an accurate picture of progress and potential delays in R&D, see appendices B, F, and I. In all the unsuccessful aircraft examined, this propensity to withhold ground truth has resulted in one of two things: program cancellation or an astronomical increase in the unit cost of the final aircraft. The only beneficiary of such a system, in which very little accountability is enforced, is the contractor; the taxpayer is unwittingly cheated and the individual service components do not get the product they require.

Another underlying factor within the civilian political framework is the large amount of retired military officers who either work for defense acquisition program officers or civilian contractors. The large majority of these men and women legitimately belongs in those positions and is by far the best qualified to do that job. However, the few exceptions that pollute those positions cost the DOD a lot of time and money in the effective development of future military weapons systems. Many of those individuals have close ties to politicians in Washington, D.C.

Secondly, the governmental politics in the nation's capital that influence aircraft development have already been touched on indirectly in the budgetary issues discussed above. However, not only do politicians in D.C. hold the purse strings to DOD equipment development and procurement, but also the interests of the contractors and manufacturers involved. This creates a curious triangle of interdependence between civilian, government, and military leaders when looking at how it affects aircraft development specifically. Aircraft are complex systems requiring many different contractors and manufacturers to develop not only the aircraft itself, but all the subsystems that go with it.

For the politician in Washington who is directly involved with legislation for aircraft development, it becomes very important that their state constituents are given an equal opportunity to share in the potential economic gains that can come from awarding contracts to manufacturers in that representative's home state. In many cases today, especially in the case of the Osprey, all fifty states are represented in the building of that platform. This may seem like a good way of creating a fair and balanced distribution of defense contracts; however, in all of the most recent aircraft programs that have been cancelled or heavily scrutinized, this sharing of the wealth has created complexities in the aircraft development process that ultimately waste money and again most importantly, time. If this trend continues, how will future aircraft development be impacted?

The answer is simple, valuable time and money will continue to be squandered in the name of fairness to U.S. companies and the DOD will continue to operate aircraft that are increasingly expensive to maintain and marginally fulfill assigned missions. This may not apply to all politicians in Washington, but given the fact that many major weapons systems like the Osprey are manufactured in all 50 states, it certainly applies to a vast majority of those representatives. This trend is definitely rooted with the politicians in national offices and can only be reversed through their willingness to change.

Lastly, the U.S. military is itself a bureaucracy that directly affects aircraft development. Interservice rivalry, individual service interests, and a general single-minded approach to the U.S. joint model of warfighting is a dangerously unchanged trend that continues to hinder joint development of aircraft. More importantly, this splintered approach to equipment development has created a strain on already tight defense budgets. Additionally, within each service there exists a certain amount of political jockeying that

has a negative impact on aircraft development. In the case of the Comanche, the U.S. Army was dealt a heavy blow by General Schoomaker, Chief of Staff of the Army, when he cancelled the program. Army leadership who had long held on to a belief that the program was vital to future operations was met with an unthinkable trump card by those Army leaders who believed otherwise. In retrospect, the aircraft was being justified as a replacement for aging Army attack and observation aircraft. This had some merit, but closer analysis reveals that those Army leaders having significant political clout, and sold on a “Silver Bullet” aircraft program, within the ranks at the time the Comanche was proposed were able to strong arm the program into a train wreck and ultimately cancellation.

The same struggle is true of the Osprey program. As previously discussed, a program that is thirty plus years in the making has given many senior leaders in the Marine Corps cause to question previous decisions to keep the program. Marine Corps leadership all agree on the value that an aircraft of this type has for expeditionary operations. However, that leadership fails to find common ground when funding for other critical programs suffer due to increased Osprey development costs. Unlike the Comanche though, USSOCCOM will receive the CV-22 version of the Osprey and probably helped mitigate any disagreement among Marine Corps leaders.

Without a doubt, the influence of political factors that inherently occur within civilian, governmental and military organizations do hinder aircraft development. The question one must ask is how can a balance of power be established amongst this tenuous triangle? Perhaps the answer is already in place.

Organization

In recent years, the government, military controls, and additional organizations have hindered effective aircraft development. At the same time processes like the Joint Requirements Oversight Council (JROC), a means of optimizing defense spending, have streamlined the procurement process and better manage meager defense dollars. Referral to organizational factors is important because of both the positive and negative impact they have on aircraft development. In the current GWOT, ad hoc organizations of political and military leaders have made possible the very efficient fielding of much needed equipment in Operation Iraqi Freedom. Granted, most of these procurements were not dealing with major weapons systems or even upgrades to major weapon systems, but they do provide a good model for change. Again, cohesive and focused aircraft development organizations were most successful in producing airframes that most closely married up with original developmental timelines. Those programs that encounter significant problems lack organization.

Successful programs find their beginnings with a well-defined and effective organization that has a vested interest in the program's success. This organization follows progress closely until either the original organization is dissolved or another organization steps up to assume the role of program oversight. Programs lacking well-defined organization lack oversight and run on autopilot until the program is in dire straights. Many sea basing initiatives being examined in concept development fall into the latter scenario; therefore, one must ask who is at the wheel of aircraft development. Evidence of this is apparent from the reaction of General Richard Myers, Chairman of the

Joint Chiefs of Staff, to a sea basing question directed to him at the 23 March 2005 Navy League annual conference.

I'm going to show my total ignorance. . . . All the chiefs are very interested in the concept and where it's going. . . . I don't think the concept is fleshed out enough to make the kind of comments you are asking me for, other than the concept is fresh, it is good and probably ties right into the theme of this year's Navy League.

Silver Bullet Theory

Although not previously identified as a potential factor contributing to aircraft development, the Silver Bullet Theory is a recurring theme in many of the previously discussed factors. First, the Silver Bullet Theory is a widely used term applied to many disciplines that refers to a single solution that will fix all problems within whatever discipline it may be applied to. For the purpose of this discussion, the Silver Bullet Theory refers to the attempt to develop a single aircraft that is capable of fulfilling many missions formerly performed by several different aircraft platforms plus potential new missions not yet being performed by legacy aircraft. Keeping this definition in mind, it is difficult to find any recent examples of aircraft that have been developed or are being developed that do not fit into this theory. The C-17 is the closest possible candidate to exist outside the Silver Bullet Theory, see appendix D. While not the sole approach to aircraft development solutions, the current paradigm leans toward production of "Silver Bullet" aircraft. Does this paradigm present potential pitfalls for aircraft development or bolster it? Most of the aircraft case studies examined in this thesis point towards the former.

The genesis of this theory potentially has its roots firmly planted in what is being called the Information Age. Many in the Pentagon subscribe to the possibility that

technology will make the uncertainty of battlefield environment a thing of the past. Ed Offley and Admiral William A. Owens in their book, *Lifting the Fog of War*, states:

The technology that is available to the U.S. military today and now in development can revolutionize the way we conduct military operations. That technology can give us the ability to see a battlefield as large as Iraq or Korea--an area 200 miles on a side--with unprecedented fidelity, comprehension, and timeliness; by night or by day, in any kind of weather, all the time. (2000, 14)

Others would say that technology has increased confusion on the battlefield. Somewhere in the middle may lie ground truth, but the proof of where DOD is heading at this time is evident in what types of aircraft platforms are currently being developed.

The V-22, F-35, and F-22 all represent multirole aircraft. The Avenger and Comanche were also developed from the beginning as multirole aircraft and both met with cancellation (see appendices B and H). What will be the demise of the current multirole/multiservice aircraft programs? Arguably the outlook is grim from what this chapter has revealed. The Osprey, despite the many challenges the program has faced, is currently the closest to actually being sent to full rate production should operational testing go without incident. However, the Joint Strike Fighter and Raptor are both in rough waters for many of the reasons already discussed, but also because each of these aircraft are being developed to fulfill many missions and in the case of the JSF, fulfill many missions for several services and for a foreign partner. What options exist? Perhaps limiting broad requirements given the contractors or maybe cancellation of more expensive programs to enable funding for cheaper multiple platforms are options that must be addressed. The implication here is that unless politicians or military leaders make a decision; history will repeat itself and each of these programs will be cancelled.

Conclusion

This chapter covered significant amounts of empirical data from historical aircraft development case studies. The result has been a validation of the potential factors that have an impact on future aircraft development, specifically aircraft that will be required to support Sea Basing. The next chapter will focus on drawing some conclusions about the factors identified, specifically which factors hold the largest potential for negatively impacting future aircraft development and on recommendations that may help mitigate those factors.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

At the moment, the army is focused on supporting costly, mature materiel concepts for limited returns. The essential point is to find the right balance between on-hand inventory based on an accurate threat analysis and an industrial base capable of surging to meet an unanticipated challenge. (2003, 256)

Macgregor, *Transformation Under Fire*

Before addressing final conclusions and recommendations in this chapter, it is prudent to review the context and purpose of this thesis. At a time when many military and civilian leaders in Washington, D.C., are trying to determine what the newest slogans and bumper stickers all mean to DOD Transformation, the global environment continues to change. In large part, responsibility for this transformation lies within a single defining moment in US history, 11 September 2001. Sea Basing is one of those changes and requires more than technology and shuffling the military infrastructure to effect a real change. Assuming military leaders advocate Sea Basing as a future capability necessary to confront the emerging environment, several enablers will be required to see that change through. Aviation assets are arguably one of the largest stumbling blocks to the effective implementation of the current Sea Basing model. The scope of this thesis has been centered on answering the question of whether or not current methods of procuring military aircraft will support production of aviation assets to support sea basing in a timely manner.

The previous chapter used seven factors identified in this research to analyze future aircraft development potential. This chapter will also use those factors as a framework for discussing research conclusions and recommendations. However, this

chapter places weight on those factors (vision, design approach, technology, funding, politics, organization, and the Silver Bullet theory) to establish the degree of prohibitive effect on future aircraft development. Immediately following the aforementioned discussion, further recommendations are offered that may or may not be directly related to aircraft development. Instead, they focus on solutions to better serve future joint force commanders in the contemporary operating environment.

Conclusions and recommendations begin with those factors that are the least problematic for aircraft development, and ends with those factors that are most problematic.

Conclusions and Recommendations

Design Approach

The defense industry has slowly moved away from its original roots of producing dependable and affordable military equipment to meet the needs of the warfighter on the physical and fiscal battlefields respectively. Applied to aircraft development today, few platforms fulfill the aforementioned needs. Interwar period (World Wars I and II) advocates of Douhet and later the bombing of Pearl Harbor, set the conditions to unleash a sleeping U.S. military industrial giant that produced aircraft like the B-17 and B-29. These were not developed in a revolutionary fashion, but through an evolutionary process of adapting known successes to the most recent proven technology available. Today, the military hedges its bets on aircraft, like the Osprey, Raptor, and JSF, aircraft that have unquestionable potential but follow an unpredictable timeline in their development. Unfortunately, history has proven that attempting to develop a quick leap in aircraft capability while ignoring proven aircraft technology is dangerous. The result is a huge

upfront cost and no aircraft as in the case of the Avenger II and Comanche. Both of these programs have and will continue to provide tremendous amounts of useful data in future aircraft development, but unfortunately those data points were bought with critical time and money that could have been better spent on aircraft designs with a higher probability for success.

A recommendation for the future is to take a more realistic approach to aircraft procurement by considering a spiral development instead of a revolutionary approach. Spiral development is the process of improving on already existing weapon systems. The premise behind spiral development is recognizing that one cannot predict the speed at which technology will progress. Given that, defense acquisition programs work to provide warfighters with adequate equipment in a timelier manner. Rather than focus on a perfect solution, program managers should fulfill the need and improve upon weapon systems as technology improves at its own pace. This recommendation does not advocate that aircraft developers should set their sights low. In fact, outside of those programs that are critical to the replacement of aging platforms or capability shortfalls, DOD should continue to allocate resources to the R&D of advanced aviation technologies. However, using unproven technologies as a basis for development of critical aircraft programs creates an unnecessary waiting time for the warfighter. Better to accept a smaller leap in capability than invest 20 to 30 years in a program that is ultimately cancelled. Again, the C-17 represents a successful case study in how well realistic incremental adaptation and refinement to previous aircraft designs can produce timely results. In the future, it would be prudent to model programs such as the B-29 and C-17.

Funding

At the beginning of this research, it seemed very obvious that funding would be a very important factor in aircraft development; and it is. However, examined within the context of this thesis, surprisingly money does not play as large a role in affecting aircraft development timelines as one might think. Rather than budgetary factors driving development timelines, the trend towards increasing procurement timelines causes higher costs for modern aircraft. The steadily increasing per copy cost of today's aircraft is largely due to the increasing length of time it takes to move from concept sketch to full rate production. It would be short sighted to not recognize that some programs are expensive from their inception. However, for the vast majority of the U.S. military's current aircraft inventory, the initial cost predicted to develop these platforms was a far cry from the final price tag. So why discuss budgeting as a potential factor at all?

It is important because both military and political leaders have developed a mindset that all new aircraft programs cost outrageous sums of money. The resulting scrutiny only exacerbates lengthy timelines. If acquisition authorities continue to believe that aircraft development will always be cost prohibitive; then funding will remain at least a minor factor in the time required to develop new aircraft.

Given the reverse logic nature of this factor, it is a little harder to fix. However, the logical place to start would be the customer. Military leaders need to consider solutions to sea base transportation problems outside of aviation. Surface vessel options, although not as fast as aviation assets, are almost always more cost effective. Secondly, Congress is a large body of very diverse interests and backgrounds. As long as a vast majority of representatives continues to seek programs that will benefit their constituents

and base their decisions on a very limited understanding of aircraft development, future aircraft development will be saddled with more and more red tape. A way to reduce this problem would be to create a more responsive legislative body, not unlike the Armed Services Committee. Such a body would not be affiliated with the House or Senate and comprised of aviation experts. Further, this body would not represent a constituency, but the Treasury Department. In this way, proposed aircraft programs are not only better assessed for potential, but affordability. This model may prove to be beneficial not only to military aviation programs, but also to development of other major weapon systems.

Organization

As discussed in the previous chapter, organizations such as the JROC and Joint Program Office have helped to streamline some procurement processes and better manage meager defense dollars. At the same time, added layers of joint control have created new procurement challenges for the individual services. No longer can the services ask for budget approval without justification of joint application. The result is an unbalanced approach to aircraft acquisition. The F-22 provides a good example of program that has been heavily scrutinized for its application to purely Air Force missions. No one would argue this; at the same time, those missions are integral to establishing air superiority in support of a larger conventional joint fight. Additional organizations and subsequent emphasis on joint requirements have given rise to a factor already discussed in this thesis, the Silver Bullet Theory. This factor will be discussed in the next section of this chapter.

As a matter of course, members of these oversight organizations have forgotten about the individual Armed Service parts that make up the whole Joint Force. The fear of

gross mismanagement and service parochialism, as demonstrated in the A-12 program, has heavily influenced the creation of the aforementioned organizations. Again, the problem is not with the organizations themselves, but with balance. This problem has no easy solution.

Ultimately, civilian members must learn to trust the military duty experts on warfighting and military members must reestablish a reputation for responsible defense spending. One way to do this is the increased use of independent third party firms, like the Government Accounting Office (GAO). The GAO already conducts in depth research in conjunction with aircraft acquisition; the JSF has been the subject of many of these studies. More reliance on firms like GAO and the RAND Corporation to provide an objective assessment of aircraft development will help find some balance. The net effect will be a reduction in the time required to make decisions on aircraft development.

Further, given the scope of joint operating concepts, like sea basing, elimination of these organizations would not be prudent. Joint oversight of programs that ultimately cost billions of dollars to develop is necessary. Future efforts to find balance within these organizations can only benefit the warfighter. A balanced oversight approach will also help program developers avoid the search for a Silver Bullet.

Silver Bullet Theory

This increasingly predominant factor not only affects aircraft development, but other military equipment procurement programs. On the whole, this factor has been both enormously beneficial and disastrous. There seems to be no middle ground with respect to this factor, especially in the case of aircraft development. History has proven that not only is it very difficult to produce an aircraft that fits every mold, but nearly impossible.

In fact, the best multirole aircraft that the U.S. military employs today are versions of previously developed, focused aircraft programs. Again, the Thunderbolt and Fighting Falcon are prime examples of this historical truth, see appendices A and E. The continued search for the aircraft that does it all feeds the imaginations of military thinkers, aircraft developers, and politicians alike. Not surprisingly, the current U.S. military aircraft procurement programs are long on time and short on progress. If this trend is to be reversed, each of the aforementioned entities needs to recognize that the time from flash to bang for such programs is in no way predictable. Assuming that the military, civilian aircraft developers and politicians could agree to recognize the unpredictable nature of aircraft development, what next?

The next step would be to revisit use of proven aircraft designs as a foundation for aircraft procurement. Given the huge overmatch capability that U.S. military aircraft have over current adversaries and those in the foreseeable future, focus should be on developing dependable and affordable aircraft in a timely manner. Spiral development of solid aircraft programs will continue to provide balance.

Vision

Continuing focus on joint integrated concepts can only make the U.S. military more effective, but the caveat to that understands which equipment, doctrine, and training that applies to. Arguably, one could make the blanket statement that joint integration is good for all the services in all situations. This is simply untrue. In the case of the Osprey, the Marine Corps has a legitimate requirement to replace aging helicopter assets. Undoubtedly, the V-22 will contribute to the larger joint fight, but justification based on that contribution should not be the driving factor behind development.

In many cases, the pressure on individual services to focus on becoming more joint creates a windfall of concepts and visions for the future that simply are not attainable at this time. With respect to aircraft development, the longer the military and politicians allow themselves to be drawn into the trap of funding high-tech ideas as solutions to current aviation shortfalls, the longer and more expensive it will be in the future before aircraft development is done in a reasonable amount of time.

This is certainly another difficult factor to counter. Again, given that the military and politicians can recognize the fixation on revolutionary leaps in capabilities, the best way to reverse this trend would be to implement some of the aforementioned recommendations. For instance, use of proven aviation technology to produce aircraft that can later be improved through spiral development has merit. Funding of S&T outside of actual procurement programs is also another option in reducing the inclination to always seek single airframes as a solution to multiple missions. However, the quickest way to mitigate the potential harmful effects of the silver bullet theory is to allow the services more freedom to develop individual aircraft to better fulfill their missions that in turn bolster joint capabilities. Arguably, each of these recommendations could have potential negative impacts on both cost and time involved in aircraft development. However, implementation of one or more of these recommendations certainly could not worsen the current significantly lengthy aircraft development timelines. Moreover, the potential for better use of developing technology would far outweigh potential negative effects.

Technology

Technology as a factor that affects aircraft development timelines has and always will be significant. In the midst of the Information Age, the biggest mistake that military leaders and politicians can make is believing that technology will continue to change at the pace it has for the past two to three decades with the advent of the computer. In fact, there has been a noticeable decrease in the steepness of the technology curve. For example, composite technology for fuselage and rotor blades has steadily tapered off and is only seeing minimal advances. More importantly has been the noticeable lack of advances in helicopter design. The V-22 demonstrates what appears to be a huge leap in helicopter design, but in fact the original tiltrotor design has been around since the early 1950s.

Approval of funding for aircraft with futuristic capabilities that rely on unpredictable advances in technology is fiscally unsound. This is simply not good business practice. Continued investment in aircraft programs that depend on unproven, and in some cases undeveloped, technologies will add to the already sky-rocketing cost of new military aircraft. Sadly, as in the case of the A-12, much of that expense is a sunk cost. More importantly, the time it takes for a platform to be made available to the warfighter is highly unpredictable. This is unacceptable.

One solution to this has already been discussed. Continue to invest in advanced technological research but proceed with caution, especially when funding R&D for technologies that support *critical* aircraft programs. Too much reliance on unpredictable technological advances can have significant negative impacts on the aircraft programs.

Most notably waste money and longer aircraft developmental timelines. The final and most critical factor in aircraft development is politics.

Politics

Of all the factors discovered in this research, none seem to be more prevalent than how much human intervention in the form of bureaucracies can make a difference. In fact, political influences can be influential not only to aircraft development directly, but to each of the aforementioned factors. This creates a situation that compounds negative effects felt by aircraft development timelines. The best example of those factors that is influenced by politics is funding. Discussed in the previous chapter are the three bureaucracies that directly affect aircraft development: (1) civilian, (2) governmental and (3) military politics. Each will be discussed separately, starting with the military.

A good starting point for change is the military. Interservice rivalry is an enduring challenge to the U.S. military in many areas, not just the aircraft acquisition process. Goldwater-Nichols was a definite step in the right direction to lessen the effects of parochialism in joint operations. This legal precedent was established in the wake of the failed hostage rescue in Iran, Operation Eagle Claw, as well as Operation Urgent Fury in Grenada. The U.S. military is currently at a similar crossroads in that history has proven aircraft development programs are failing to provide warfighters with needed assets due largely to the politics that are ongoing between the armed services. This is evident in when one observes the simultaneous development of the F-35, V-22, F-22, RAH-66, and C-17 programs at one point in time. The C-17 is the only aircraft providing a capability to the warfighter at this time. This practice is not supportable under current fiscal constraints

on defense spending. Few would advocate more legal red tape to further complicate an already cumbersome process; the follow recommendation is not suggesting that.

In addition to current legal mandates for budgeting, it would be advantageous to establish a legal means of forcing the armed services to come to the table collectively in matters concerning joint development of major end items. This would be especially helpful in expensive aircraft development programs. At first, this may seem counter to recommendations made concerning the Silver Bullet theory. This is not a mandate for multirole aircraft. Instead, it is a mandate for a single platform to replace the capabilities of two or more platforms that fulfill like missions, just in different services. The H-60 helicopter is the prime example of how well this can work. The H-60 is used by three of the four armed services, as well as the Coast Guard and U.S. Special Operations Command.

Another recommendation to lessen the potential for military bureaucracy is more oversight from an outside impartial party. This oversight could be conducted by either trusted retired military or civilians with who have requisite knowledge and background in not only aviation but also business. This would help to maintain the broader joint purpose for aircraft development at the forefront of the service branches involved. Secondly, additional past and present perspectives to aviation development outside the current military paradigms would be helpful in looking developing alternatives. Lastly, few military leaders have any experience outside the military in business practices.

Ultimately, military leaders are ill equipped to deal with contractors outside of military factors involved in aircraft development. Outside oversight from civilians with business savvy would potentially help bring sanity to the arguments between services over aircraft

development potential, especially with regard to realistic development timelines. The next bureaucracy discussed is civilian contractors.

As previously discussed in chapter 4, two distinct problems exist in the world of the contractors used for aircraft development, lack of accountability and former military employees. The lack of accountability is primarily a function of what has been previously discussed in this chapter with respect to available technology. As long as contracts continue to be written to develop aircraft based on forecasted technologies, it will be difficult to hold contractors accountable; they are simply not to blame. Two things can help prevent this: (1) realistic aircraft development goals and (2) peer competition until later in the development process.

First, the U.S. military must set more realistic goals in the type of aircraft technology it is willing to develop. The civilian contracting community is not to blame for delayed timelines and over budget problems if the military enters contracts for unpredictable advanced aircraft programs. Also, legal accountability must be in place for failure of aircraft contractors to meet contractual agreements caused by factors within their control. As seen, this recommendation requires efforts on the part of not only the civilian contractors, but also the military.

Second, quite often contracts are awarded to single aircraft manufacturers before the program is mature enough to have a reasonable rate of success. This is especially true in the case of the Osprey. Granted, the number of helicopter manufacturers has dwindled to two, but the prospect of international helicopter companies was barely considered. This is in large part due to the tremendous lobbying efforts that take place in Washington, D.C. The reality of this problem is that it has no simple solution. Either create incentives

for the potential development of more aircraft industry in the United States or look overseas for partners to help in development of new aircraft. The first case would take years and the latter is almost unspeakable given the overreliance the U.S. already has on overseas industry. Recommendations for the first two political entities discussed have been heavily focused on government intervention; that segues into a discussion of governmental politics.

The largest underlying factor identified in this research is the effect that government leaders in D.C. have on aircraft development. The problem lies in the propensity to put constituency before the needs of the armed services. It would be easy to recommend that all U.S. representatives should make a sharp u-turn in the way that they approach their votes for future military aircraft development programs; however, that is not realistic. Outside of legislative change to impose better control measures in how lobbyists and others influence these representatives, the future does not look bright for change. Especially when one considers how long most new legislation takes to pass Congress. The bureaucracy contained within our democratic system is arguably the means by which checks and balances are achieved. However, when the lives of U.S. servicemen are endangered for personal gain, it is time for change.

Better telling the military's story to Congress may hold potential for a rebirth of moral and ethical decision making from U.S. representatives. However, this will require more effort on the part of the individual services to speak from a position of unity. At this time, interservice rivalry and the quest for relevance threaten to keep the military divided. Worst of all, the military continues to air its dirty laundry in front of civilian leadership. Assuming this problem can at least be mollified; a unified approach to requesting funding

approval for aircraft acquisition gives Congress no excuses. The potential for more effective use of meager defense dollars is definitely possible. Moreover, congressmen may find a better balance between support of the warfighter and their constituents. Ultimately, responsible government leadership and a renewed partnership with the military hold potential to shorten the aircraft development process.

The negative influence from military, civilian, and governmental politics on aircraft development is undeniable. At the same time, history has shown that a cooperative effort from within and between each of these entities has a positive effect on fostering successful programs. However, recent history is proving that one or two and maybe all of these entities are allowing internal interests to hinder aircraft development. Of all the previously discussed factors that have a negative impact on aircraft development, none are more prevalent than politics. It will take a combined effort from the armed services, government contractors and representatives in Washington to mitigate lengthy developmental timelines for future aircraft development.

Further Recommendations

The following is a short set of further recommendations that do not fit neatly into one of the previously discussed areas. Some could have significantly positive effects in mitigating any number of the previous factors and thus improving aircraft development timelines. Others may not offer solutions to reducing those timelines, but provide options with huge potential outside of new aircraft development to support sea basing.

The trend towards aviation dominance has blinded many senior military leaders to the usefulness of other joint force capabilities. In an age when speed is everything to everyone, the aircraft has become the answer to all problems. Although not the primary

research question in this thesis, the underlying concept of sea basing is definitely supported by this research. This is proof that some forward thinkers are recognizing that the sea has and always will be an area in which the U.S. can project force and posture for potential military action. In the future, decreasing access to potential ports and airfields of entry, increasing cost of maintaining overseas bases, and a shift from state to non-state aggressors is leading many to place more emphasis on the importance of using the sea as a maneuver space. Thus, it would be advantageous to further investigate the potential for more surface vessels to both posture and move additional military power when and where it is needed. Although initially surface platforms are more costly, they are far less expensive over the long term. This is not a recommendation to drastically reduce aviation assets in the military. That is unrealistic and ignorant of aviation's usefulness on the battlefield. It is an appeal to military and civilian leaders to take broader look at options other than aircraft to fulfill mission sets historically accomplished by aviation assets.

Off-the-shelf technology from U.S. and foreign civilian industry has proven to be both good for the pocket book and beneficial to fulfilling the needs of troops in the field. Shotguns, all terrain vehicles, navigational aids, and small radios are just a few examples. In the future, it would be advantageous to explore use of commercially produced aircraft from both U.S. and foreign manufacturers. This is certainly not a new idea when one considers the fact that the military currently contracts the use of civilian aircraft through the Civil Reserve Air Fleet. Additionally, the U.S. military does purchase limited amounts of aircraft, such as the C-21, DC-9, B707, and others, to fulfill VIP, command and control, and refuel missions. With minimum modifications, each of these aircraft has performed admirably in their respective missions at a huge savings in time and money.

The same could be true for mission sets that require larger numbers of aircraft. This would not only create cost savings, but also provide timelier fulfillment of operational needs statements. Lastly, the already established logistical infrastructure to support OTS platforms definitely saves time and money.

Currently, the Army, Marine Corps, and Special Operations Command are the major contributors of ground forces that require aviation support. The Army is the only one who does not have a significant fixed-wing capability. For many reasons, to include command and control, fires, intelligence collection, intratheater lift, and logistics missions, it would be advantageous to give the Army back an air corps. This recommendation does not advocate dismantling the Air Force. Instead, it allows the Air Force to focus on joint specialty missions like intertheater lift, joint airspace control, and strategic bombing. This would also give the Army more capability to effectively conduct its given missions sets on the ground. The linkage between this recommendation and aircraft development timelines is somewhat obscured on the surface. However, the biggest reason that this would help in the aircraft acquisition process is that it would put supported ground force providers in control of aircraft development and out of the hands of a service branch that is disconnected from the aforementioned services. It is arguable that this may create further parochialism, but in light of both past and recent interservice rivalry challenges discussed in this research, it is more likely that the situation could only improve.

Lastly, recognizing a good thing when you have it is important. In the future, it would be beneficial to retain the ability to manufacture new airframes that replace aging but capable aircraft. For example, although the CH-46 Sea Knight is being replaced by

the Osprey, this aircraft has undergone many service life extensions to preserve the airframes. The ability to build new Sea Knights would have save billions of dollars while waiting for the Osprey. Also, considering the process of spiral development, these new airframes could receive the latest in evolutionary technology to adequately provide for the needs of the warfighter. Arguably the future may require newly developed aircraft to counter unforeseen threats and mission sets. However, based on the huge overmatch in U.S. military capabilities, especially in aircraft, it seems counter productive to continue to engage in an arms race with ourselves.

Adaptation of already capable aircraft and replacement of aging airframes instead of opting for expensive Service Life Extension Programs would definitely save money in the long term. More importantly, the warfighter would see his aviation needs met faster when compared to the time it takes to currently develop aircraft. Further, this cost savings could be passed on to more intensive Science and Technology research that could reduce the time required to develop future aircraft.

None of these further recommendations offer the sole answer to reducing aircraft development timelines. Nor do they offer alternatives that will solve the high cost in terms of time and money to produce new aircraft. Instead, collectively these recommendations offer options that are worth further investigation to verify potential alternatives to aircraft development.

Conclusion

The potential for sea basing is unlimited. Again, this is not a new concept. However, the capability of employing joint and coalition forces from the sea without the need to initially seize lodgments ashore has potential to be revolutionary. Aviation assets

to support this endeavor are critical. The largest stumbling block in the way at this time is *time*. If a trend of elongated aircraft development timelines continues, the potential for wasting precious resources is imminent.

Efforts that are ongoing to better synchronize an all service involvement in the development of sea basing are a step in the right direction. However, the challenge will be to maintain momentum in a positive direction while some senior leaders lose focus on long term transformation efforts.

Finally, this research has uncovered some potential topic areas outside of aircraft development to support Sea Basing that would potentially be useful as future sea base research topics. First, a more in depth analysis of sea lift versus air lift to support sea basing operations would help bring up to date the analysis already done by the Government Accounting Office. As previously recommended, sealift is a very efficient way of moving and posturing military forces. In those cases where effectiveness outweighs efficiency, the application of aviation assets is critical; however, ignorance of potential sealift options outside the realm of what can be accomplished by aircraft would be shortsighted.

Further research, from a historical perspective, on the usefulness of integrating the efforts of both joint and coalition partners in the overall sea basing concept development would prove to be useful to senior military planners who are convinced that the future lies in the big “J” in joint operations. Continued focus by only the Navy and Marine Corps to develop sea basing from a purely U.S. maritime perspective only sets the U.S. up to learn many of history’s lessons again.

As a more focused topic recommendation, the feasibility of posturing U.S. Army forces at sea is certainly worth investigation. Currently, the Army is transforming to provide the means to move an entire brigade's worth of men and material to the fight with aviation. Worthy of analysis is how Regional Component Commanders might benefit from having not only Marine Expeditionary Units at their beckon call, but an entire brigade. The Army is already familiar with use of shipping to posture and move material, so it is not that big a stretch to think that the Army could posture soldiers at sea.

Finally, as the ultimate recipient of forces from the sea, involvement of both Regional Component Commanders and future Standing Joint Force Headquarters in the development of future sea basing is critical. Focused research to show the importance of this contribution to sea base development would prove useful. Especially to the U.S. Joint Forces Command, which is not considering the potential synchronization problems in the future. At this time, Joint Forces Command has devoted significant effort to joint training and joint staff structures for the future. However, it should also get involved with sea base concept development. At this time, sea basing is a Joint Integrating Concept in name only. The potential for huge sums of wasted money and more importantly, wasted time, may prove to be one of the most expensive lessons learned in the entire history of U.S. military evolution.

APPENDIX A

AIRCRAFT RESEARCH DATA: A-10/OA-10 THUNDERBOLT II

All references to quantitative and qualitative aircraft data in this appendix are from the Federation of American Scientists website unless otherwise noted with an appropriate parenthetical reference.

The A-10 Thunderbolt II is the first Air Force aircraft specially designed for close air support of ground forces. They are simple, effective, and survivable twin-engine jet aircraft that can be used against all ground targets, including tanks and other armored vehicles. The primary mission of the A-10 is to provide day and night close air combat support for friendly land forces and to act as forward air controller (FAC) to coordinate and direct friendly air forces in support of land forces. The A-10 has a secondary mission of supporting search and rescue and Special Forces operations. It also possesses a limited capability to perform certain types of interdiction. All of these missions may take place in a high or low threat environment.

The A/OA-10 aircraft was specifically developed as a close air support aircraft with reliability and maintainability as major design considerations. The Air Force requirements documents emphasized payload, low altitude flying capability, range and loiter capability, low speed maneuverability and weapons delivery accuracy. The aircraft is capable of worldwide deployment and operation from austere bases with minimal support equipment.

Specific survivability features include titanium armor plated cockpit, redundant flight control system separated by fuel tanks, manual reversion mode for flight controls, foam filled fuel tanks, ballistic foam void fillers, and a redundant primary structure providing "get home" capability after being hit. Design simplicity, ease of access and left to right interchangeable components make the A/OA-10 aircraft readily maintainable and suitable for deployment at advanced bases.

The A-10/OA-10 has excellent maneuverability at low air speeds and altitude, and is highly accurate weapons-delivery platforms. They can loiter near battle areas for extended periods of time and operate under 1,000-foot ceilings (303.3 meters) with 1.5-mile (2.4 kilometers) visibility. Their wide combat radius and short takeoff and landing capability permit operations in and out of locations near front lines. Using night vision goggles, A-10/ OA-10 pilots can conduct their missions during darkness.

The A/OA-10 is a single place, pressurized, low wing, and tail aircraft with two General Electric TF-34-100/A turbo-fan engines, each with a sea level static thrust rating of approximately 9000 pounds. The engines are installed in nacelles mounted on pylons extending from the fuselage just aft of and above the wing. Two vertical stabilizers are located at the outboard tips of the horizontal stabilizers. The forward retracting tricycle

landing gear incorporates short struts and a wide tread. The nose wheel retracts fully into the fuselage nose. The main gear retracts into streamlined fairing on the wing with the lower portion of the wheel protruding to facilitate emergency gear-up landings. The General Electric Aircraft Armament Subsystem A/A49E-6 (30 millimeter Gun System) is located in the forward nose section of the fuselage. The gun system consists of the 30mm Gatling gun mechanism, double-ended linkless ammunition feed, storage assembly and hydraulic drive system.

Avionics equipment includes communications, inertial navigation systems, fire control and weapons delivery systems, target penetration aids and night vision goggles. Their weapons delivery systems include head-up displays that indicate airspeed, altitude and dive angle on the windscreen, a low altitude safety and targeting enhancement system (LASTE) which provides constantly computing impact point freefall ordnance delivery; and Pave Penny laser-tracking pods under the fuselage. The aircraft also have armament control panels, and infrared and electronic countermeasures to handle surface-to-air-missile threats.

The Thunderbolt II's 30mm GAU-8/A Gatling gun can fire 3,900 rounds a minute and can defeat an array of ground targets to include tanks. Some of their other equipment includes an inertial navigation system, electronic countermeasures, target penetration aids, self-protection systems, and AGM-65 Maverick and AIM-9 Sidewinder missiles.

Thunderbolt IIs have Night Vision Imaging Systems (NVIS), compatible single-seat cockpits forward of their wings and a large bubble canopy which provides pilots all-around vision. The pilots are encircled by titanium armor that also protects parts of the flight-control system. The redundant primary structural sections allow the aircraft to enjoy better survivability during close air support than did previous aircraft. The aircraft can survive direct hits from armor-piercing and high-explosive projectiles up to 23mm. Their self-sealing fuel cells are protected by internal and external foam. Their redundant hydraulic flight-control systems are backed up by manual systems. This permits pilots to fly and land when hydraulic power is lost.

The Thunderbolt II can be serviced and operated from bases with limited facilities near battle areas. Many of the aircraft's parts are interchangeable left and right, including the engines, main landing gear and vertical stabilizers.

The first production A-10A was delivered to Davis-Monthan Air Force Base, Ariz., in October 1975. It was designed specially for the close air support mission and had the ability to combine large military loads, long loiter and wide combat radius, which proved to be vital assets to America and its allies during Operation Desert Storm. In the Gulf War, A-10s, with a mission capable rate of 95.7 percent, flew 8,100 sorties and launched 90 percent of the AGM-65 Maverick missiles.

The original service life of the A/OA-10 was 8,000 hours, equating to approximately to FY2005. The revised service life was projected out to 12,000 hours,

equating to approximately FY2016. The most recent long range plan has the A/OA-10 in the fleet through FY2028, which equates to approximately 18,000-24,000 hours.

A/OA-10 modifications are designed to improve the A/OA-10 throughout its service life. All modifications are integrated between ACC, AFRC, and ANG, with the Guard and Reserve often funding non-recurring engineering efforts for the modifications and ACC opting for follow-on production buys. Budgetary constraints are often best overcome by this type of arrangement. Two types of modifications are conducted on the A/OA-10, those to systems, structures and engines, and those to avionics. Structure, system and engine modifications aim at improving reliability, maintainability, and supportability of the A/OA-10 and reducing the cost of ownership. Avionics modifications continue the metamorphosis of the A/OA-10 from a day visual flight rules (VFR) fighter to a night-capable integrated weapon system.

A/OA-10 avionics modifications provide for greater interoperability between the Army and Air Force by improving situational awareness, tactical communication, navigation and weapon system accuracy, and providing additional capabilities in the areas of threat detection and avoidance, low-level flight safety, stores management and employment of “smart” weapons. In addition, modifications are sought to reduce cost of ownership and to remove supportability quagmires such as obsolete parts. Modifications to the A/OA-10 are nearly always interdependent--interdependence maximizes combat capability of the A/OA-10 by interconnecting modifications in distributed avionics architecture. Integral to the improvement of the A/OA-10 is a new acquisition strategy centered on a recently acquired prime contractor for the weapon system. The prime contractor will be the integrator of all major weapon system modifications and provide the continuity necessary to accommodate the downward trend in organic manpower and relocation of the System Program Office.

A large portion of the systems sustaining engineering is for contingency use throughout the fiscal year and is utilized to investigate mishaps, resolve system deficiencies, develop engineering change proposals, or to establish new operational limits. Specific requirements cannot be forecast, but general needs can be predicted based on actual occurrences since the A/OA-10 program management responsibility transferred to SM-ALC in 1982. The objectives of the sustaining engineering and configuration management programs are to reduce spares utilization, reduce hazard potentials and to increase the weapon system's effectiveness. Sustaining Engineering is mission critical and will be used to obtain the non-organic engineering services needed to maintain and improve the design and performance.

The A/OA-10 weapon system was originally designed for manual pilot operation and control. In 1990, the aircraft was modified to incorporate the Low Altitude Safety and Targeting Enhancements (LASTE) System. This system provided computer-aided capabilities including a Ground Collision Avoidance System (GCAS) to issue warnings of impending collision with the ground, an Enhanced Attitude Control (EAC) function for aircraft stabilization during gunfire and a Low Altitude Autopilot system, and

computed weapon delivery solutions for targeting improvements. The LASTE computer system installation added the requirement for an Operational Flight Program (OFP) to provide the computer control software necessary to perform the above functions. Commencing in 1999, the A/OA-10 fleet was additionally upgraded with the installation of an Embedded Global Positioning System/Inertial Navigation System (EGI). In conjunction with this aircraft modification, a replacement Control Display Unit (CDU) will be installed with its own separate OFP software.

Operational capability changes, mission changes, latent system deficiencies, and additional user requirements dictate the necessity of periodic OFP block change cycles (BCC) to maintain the weapon system operational requirements. The current BCC includes the LASTE OFP changes, but will additionally require the CDU OFP updates to be accomplished concurrently following the installations of EGI/IDM Modification. Following installation of the original LASTE System, corrections to original system deficiencies, added user requirements, and now the pending EGI modification program have increased the total requirements for the LASTE computer hardware to its maximum design capability. Implementation of the current OFP software change will result in maximum utilization of the computer's memory and throughput, precluding any further operational change requirements from being implemented. In anticipation of this hardware limitation, engineering Reliability and Maintainability (R&M) project was initiated in 1993 to develop options to correct this deficiency. This project is developing an engineering hardware unit, along with an updated OFP software program, for test and evaluation.

The addition of the LASTE system and the pending installation of the EGI/CDU system have greatly increased the complexity of the A/OA-10 weapon system, including the troubleshooting and maintenance requirements. Also, the implementation of the 2-level maintenance system, eliminating the intermediate-level maintenance capabilities at the operating units, has necessitated improved troubleshooting capabilities at the unit levels to maintain the aircraft operational readiness requirements. An Operational Test System (OTS) has been developed to provide a computer test aid for the organizational maintenance units to expedite their maintenance actions. The OTS contains a software test program that requires periodic updates to maintain compatibility with the LASTE and CDU systems, as well as other A/OA-10 avionics systems.

TF-34 engines are essentially two level maintenance via user Queen Bee sites at Barksdale, Davis-Monthan and Shaw AFBs. All ACC aircraft TF-34 engines are repaired at Davis-Monthan or Shaw AFB. Shaw AFB also supports USAFE. PACAF uses a combination of two and three level maintenance; Osan AB utilizes regional support provided at Kadena AB, while Eielson AFB performs Jet Engine Intermediate Maintenance (JEIM) on-sight. Barksdale AFB regionally supports AFRC. The ANG remains entirely supported by base field JEIM shops. Depot level engine maintenance is accomplished by the Navy at Jacksonville NAS, FL. The A/OA-10 has 51 avionics line replaceable units that transitioned to two level maintenance.

The A/OA-10 was designed for user maintenance in all normal maintenance inspections and tasks. This design has been very successful for this aspect and there is every expectation this will continue for the life of the weapon system. The only depot level requirements are Analytical Condition Inspection (ACI) and unscheduled depot level repair.

ACI is a specialized inspection to check areas, sub-systems or parts that are not checked on any periodic basis during normal maintenance. The purpose of the ACI is to find developing problems that might affect the mission or ensure such conditions do not exist. Problems discovered during ACI result in engineering studies that determine appropriate corrective action. There are 11 ACI aircraft selected (by usage, age, flight hours and environment) from different bases and MAJCOMs that are scheduled per fiscal year. The ACIs are accomplished at OO-ALC.

Unscheduled depot repair occurs when an aircraft incident, accident or other unusual occurrence creates a problem beyond the user's ability to correct. Such occurrences result in a request from the MAJCOM for depot assistance. Depending on the situation, the aircraft may be inducted into a depot or contractor facility, or a depot or contractor field team may be dispatched to the location of the aircraft.

The A/OA-10 has a requirement for repaint every eight years. The fleet size sets the current requirement to approximately 65 per fiscal year. While this is not strictly a depot requirement, the need for a fixed, specialized and environmentally contained facility limits the user in his choices. The A/OA-10 is primarily painted at OO-ALC; however, Daimler-Benz AG in Germany paints USAFE aircraft. For economic reasons the 11 ACI aircraft inducted into OO-ALC each year are also painted.

APPENDIX B

AIRCRAFT RESEARCH DATA: A-12 AVENGER II

All references to quantitative and qualitative aircraft data in this appendix are from the Federation of American Scientists website unless otherwise noted with an appropriate parenthetical reference.

Plans for the Navy's A-12 combat aircraft called for incorporating more advanced stealthy characteristics than were used in the F-117A, as well as significantly greater payload capabilities. The Navy's A-12 Avenger Advanced Technology Aircraft (ATA) was slated to replace current A-6s on aircraft carriers in the mid-1990's. But on 7 January 1991, Secretary of Defense Richard Cheney canceled the program, in the largest contract termination in DOD history. By one estimate the A-12 had become so expensive that it would have consumed up 70 percent of the Navy's aircraft budget within three years.

The Navy originally planned to buy 620 of the McDonnell Douglas/General Dynamics aircraft, with the Marine Corps purchasing an additional 238 planes. And the Air Force at one point considered buying 400, at an average cost that was estimated at close to \$100 million each. The A-12 was designed to fly faster and further than the A-6E, and carry a large bomb-load in internal bomb-bays to reduce drag and maintain a low radar cross-section. As with the Advanced Tactical Fighter (ATF), the A-12 was expected to have greater reliability than current aircraft (double that of the A-6E), and require half the maintenance manhours.

At first blush, the A-12's performance capabilities would have been in roughly the same class as existing aircraft. The key improvement over existing aircraft, not inherently obvious when comparing specifications, was stealth. While today's radar can detect existing naval aircraft at a range of 50 miles, the A-12 was designed to remain undetected until approximately 10 miles away. This would result in significant operational and survival benefits for the A-12 since defenders would have little opportunity to engage the aircraft once detected so close to the target. The A-12's reduced radar cross section would have been derived, in part, from carrying its ordnance internally. While the top speed of the more visible F/A- 18 and A-6 would be significantly reduced by the drag induced by external weapons carriage, the internal weapons bay on the A-12 would provide no impediment to speed.

The A-12 proved to be the most troubled of the new American stealth aircraft in large part because of problems found in the extensive use of composites in its structure. These composites did not result in anticipated weight savings, and some structural elements had to be replaced with heavier metal components. The weight of each aircraft exceeded 30 tons, 30% over design specification, and close to the limits that could be accommodated on aircraft carriers. The program also experienced problems with its

complex Inverse Synthetic Aperture Radar system, as well as delays in its advanced avionics components.

The full scope of these problems were not appreciated at the time of Defense Secretary Cheney's Major Aircraft Review, which slowed the production rate and dropped 238 Marine Corps aircraft, leaving the original total Navy buy of 620 aircraft. Cheney also decided to delay for over 5 years the Air Force buy (from 1992 to 1998), which was decoupled from the Navy project. Subsequently, the A-12 contractors revealed that the project faced serious engineering problems and a \$2 billion cost overrun, which would delay the first flight by over a year, to the fall of 1991, and raised the unit cost substantially.

According to the 1990 administrative inquiry conducted for the Secretary of the Navy, the cost performance data from the A-12 contractors clearly indicated significant cost and schedule problems. The results of an oversight review of the cost performance reports disclosed that the A-12 contract would probably exceed its ceiling by \$1 billion. However, neither the contractors nor the Navy program manager relied upon this data; instead, they used overly optimistic recovery plans and schedule assumptions. The inquiry concluded that the government and contractor program managers lacked the objectivity to assess the situation and they disregarded financial analysts who surfaced the problems.

The U.S. Navy on January 7, 1991, notified McDonnell Douglas and General Dynamics Corporation (the Team) that it was terminating for default the Team's contract for development and initial production of the A-12 aircraft, and demanded repayment of the amounts paid to the Team under such contracts. The Department of Defense terminated the contract after the contractors failed to deliver a single airplane after receiving more than \$2 billion in payments. Instead, the contractors refused to continue with the contract unless they received extraordinary relief in the form of relaxed terms and extra funds. At the same time, they would or could not assure delivery of an aircraft by a time certain, specify the aircraft's performance capabilities, or commit to a specific price for the aircraft. The Team filed a legal action to contest the Navy's default termination, to assert its rights to convert the termination to one for "the convenience of the Government," and to obtain payment for work done and costs incurred on the A-12 contract but not paid to date.

On December 19, 1995, the U.S. Court of Federal Claims ordered that the Government's termination of the A-12 contract for default be converted to a termination for convenience of the Government. On December 13, 1996, the Court issued an opinion confirming its prior no-loss adjustment and no-profit recovery order. In an early 1997 stipulation, the parties agreed that, based on the prior orders and findings of the court, plaintiffs were entitled to recover \$1.071 billion. Furthermore, on January 22, 1997, the court issued an opinion in which it ruled that plaintiffs are entitled to recover interest on that amount.

The government appealed the United States Court of Federal Claims ruling of 20 February that awarded \$1.2 billion to Boeing and General Dynamics. The Department of Defense argued that the court incorrectly ruled in favor of the contractors and that the award provides unwarranted relief from a failure to produce the aircraft for which the contractors were fully responsible. The Federal Claims Court decision was fully expected based upon earlier rulings by the trial judge; the government has made clear its belief that those earlier rulings were fundamentally flawed. A US Appeals Court overturned the award to Boeing and General Dynamics in July 1999, ruling that trial judge used the wrong legal test before issuing the damage awards. The trial judge reversed himself in September 2001, ruling that the government was justified in canceling the A-12 program. The issue remains unsettled, interrupting the Navy's FY 2003 procurement agenda because lawmakers want the case settled before awarding an \$810 million contract for third DDG-51 destroyer to Bath Iron Works (BIW), a subsidiary of Boeing.

APPENDIX C

AIRCRAFT RESEARCH DATA: AH-64 APACHE

All references to quantitative and qualitative aircraft data in this appendix are from the Federation of American Scientists website unless otherwise noted with an appropriate parenthetical reference.

The Boeing (McDonnell Douglas) (formerly Hughes) AH-64A Apache is the Army's primary attack helicopter. It is a quick-reacting, airborne weapon system that can fight close and deep to destroy, disrupt, or delay enemy forces. The Apache is designed to fight and survive during the day, night, and in adverse weather throughout the world. The principal mission of the Apache is the destruction of high-value targets with the HELLFIRE missile. It is also capable of employing a 30MM M230 chain gun and Hydra 70 (2.75 inch) rockets that are lethal against a wide variety of targets. The Apache has a full range of aircraft survivability equipment and has the ability to withstand hits from rounds up to 23MM in critical areas.

The AH-64 Apache is a twin-engine, four bladed, multi-mission attack helicopter designed as a highly stable aerial weapons-delivery platform. It is designed to fight and survive during the day, night, and in adverse weather throughout the world. With a tandem-seated crew consisting of the pilot, located in the rear cockpit position and the co-pilot gunner (CPG), located in the front position, the Apache is self-deployable, highly survivable and delivers a lethal array of battlefield armaments. The Apache features a Target Acquisition Designation Sight (TADS) and a Pilot Night Vision Sensor (PNVS) which enables the crew to navigate and conduct precision attacks in day, night and adverse weather conditions.

The Apache can carry up to 16 Hellfire laser designated missiles. With a range of over 8000 meters, the Hellfire is used primarily for the destruction of tanks, armored vehicles and other hard material targets. The Apache can also deliver 76, 2.75" folding fin aerial rockets for use against enemy personnel, light armor vehicles and other soft-skinned targets. Rounding out the Apache's deadly punch are 1,200 rounds of ammunition for its Area Weapons System (AWS), 30MM Automatic Gun.

Powered by two General Electric gas turbine engines rated at 1890 shaft horsepower each, the Apache's maximum gross weight is 17,650 pounds which allows for a cruise airspeed of 145 miles per hour and a flight endurance of over three hours. The AH-64 can be configured with an external 230-gallon fuel tank to extend its range on attack missions, or it can be configured with up to four 230-gallon fuel tanks for ferrying/self-deployment missions. The combat radius of the AH-64 is approximately 150 kilometers. The combat radius with one external 230-gallon fuel tank installed is approximately 300 kilometers [radii are temperature, PA, fuel burn rate and airspeed dependent]. The AH-64 is air transportable in the C-5, C-141 and C-17.

An on-board video recorder has the capability of recording up to 72 minutes of either the pilot or CPG selected video. It is an invaluable tool for damage assessment and reconnaissance. The Apache's navigation equipment consists of a doppler navigation system, and most aircraft are equipped with a GPS receiver. The Apache has state of the art optics that provide the capability to select from three different target acquisition sensors. These sensors are

Day TV - Views images during day and low light levels, black and white.
TADS FLIR - Views thermal images, real world and magnified, during day, night and adverse weather.
DVO - Views real world, full color, and magnified images during daylight and dusk conditions.

The Apache has four articulating weapons pylons, two on either side of the aircraft, on which weapons or external fuel tanks can be mounted. The aircraft has a LRF/D. This is used to designate for the Hellfire missile system as well as provide range to target information for the fire control computer's calculations of ballistic solutions.

Threat identification through the FLIR system is extremely difficult. Although the AH-64 crew can easily find the heat signature of a vehicle, it may not be able to determine friend or foe. Forward looking infrared detects the difference in the emission of heat in objects. On a hot day, the ground may reflect or emit more heat than the suspected target. In this case, the environment will be "hot" and the target will be "cool". As the air cools at night, the target may lose or emit heat at a lower rate than the surrounding environment. At some point the emission of heat from both the target and the surrounding environment may be equal. This is IR crossover and makes target acquisition/detection difficult to impossible. IR crossover occurs most often when the environment is wet. This is because the water in the air creates a buffer in the emissivity of objects. This limitation is present in all systems that use FLIR for target acquisition.

Low cloud ceilings may not allow the Hellfire seeker enough time to lock onto its target or may cause it to break lock after acquisition. At extended ranges, the pilot may have to consider the ceiling to allow time for the seeker to steer the weapon onto the target. Pilot night vision sensor cannot detect wires or other small obstacles.

Overwater operations severely degrade navigation systems not upgraded with embedded GPS. Although fully capable of operating in marginal weather, attack helicopter capabilities are seriously degraded in conditions below a 500-foot ceiling and visibility less than 3 km. Because of the Hellfire missile's trajectory, ceilings below 500 feet require the attack aircraft to get too close to the intended target to avoid missile loss. Below 3 km visibility, the attack aircraft is vulnerable to enemy ADA systems. Some obscurants can prevent the laser energy from reaching the target; they can also hide the target from the incoming munitions seeker. Dust, haze, rain, snow and other particulate matter may limit visibility and affect sensors. The Hellfire remote designating crew may

offset a maximum of 60 degrees from the gun to target line and must not position their aircraft within a +30-degree safety fan from the firing aircraft.

The Apache fully exploits the vertical dimension of the battlefield. Aggressive terrain flight techniques allow the commander to rapidly place the ATKHB at the decisive place at the optimum time. Typically, the area of operations for Apache is the entire corps or divisional sector. Attack helicopters move across the battlefield at speeds in excess of 3 kilometers per minute. Typical planning airspeeds are 100 to 120 knots during daylight and 80 to 100 knots at night. Speeds during marginal weather are reduced commensurate with prevailing conditions. The Apache can attack targets up to 150 km across the FLOT. If greater depth is required, the addition of ERFS tanks can further extend the AH-64's range with a corresponding reduction in Hellfire missile carrying capacity (four fewer Hellfire missiles for each ERFS tank installed).

Apache production began in FY82 and the first unit was deployed in FY86. As of November 1993, 807 Apaches were delivered to the Army. The last Army Apache delivery is scheduled for December 1995. Thirty-three attack battalions are deployed and ready for combat. The Army is procuring a total of 824 Apaches to support a new force structure of 25 battalions with 24 Apaches for each unit (16 Active; 2 Reserve; 7 National Guard) under the Aviation Restructure Initiative. The Apache has been sold to Israel, Egypt, Saudi Arabia, the UAE, and Greece.

The AH-64 fleet consists of two aircraft models, the AH-64A and the newer Longbow Apache (LBA), AH-64D. AH-64A model full-scale production began in 1983 and now over 800 aircraft have been delivered to the U.S. Army and other NATO Allies. The U.S. Army plans to remanufacture its entire AH-64A Apache fleet to the AH-64D configuration over the next decade. The AH-64A fleet exceeded one million flight hours in 1997, and the median age of today's fleet is 9 years and 1,300 flight hours.

The AH-64A proved its capabilities in action during both Operation Restore Hope and Operation Desert Storm. Apache helicopters played a key role in the 1989 action in Panama, where much of its activity was at night, when the AH-64's advanced sensors and sighting systems were effective against Panamanian government forces.

Apache helicopters also played a major role in the liberation of Kuwait. On 20 November 1990, the 11th Aviation Brigade was alerted for deployment to Southwest Asia from Storck Barracks in Illesheim Germany. The first elements arrived in theater 24 November 1990. By 15 January 1991 the unit had moved 147 helicopters, 325 vehicles and 1,476 soldiers to the region. The Apache helicopters of the Brigade destroyed more than 245 enemy vehicles with no losses.

During Operation Desert Storm, AH-64s were credited with destroying more than 500 tanks plus hundreds of additional armored personnel carriers, trucks and other vehicles. They also were used to destroy vital early warning radar sites, an action that opened the U.N. coalition's battle plan. Apaches also demonstrated the ability to perform

when called upon, logging thousands of combat hours at readiness rates in excess of 85 percent during the Gulf War.

While recovery was ongoing, additional elements of the 11th Aviation Brigade began the next chapter of involvement in the region. On 24 April 1991 the 6th Squadron, 6th Cavalry's 18 AH-64 helicopters began a self-deployment to Southwest Asia. The Squadron provided aerial security to a 3,000 square kilometer region in Northern Iraq as part of the Combined Task Force of Operation Provide Comfort.

And the AH-64A Apache helped to keep the peace in Bosnia. April of 1996 saw the beginning of the 11th Regiment's involvement in Bosnia-Herzegovina. Elements of 6-6 Cavalry served as a part of Task Force Eagle under 1st Armored Division for 7 months. In October of 1996, Task Force 11, consisting of the Regimental Headquarters, 2-6 Cavalry, 2-1 Aviation and 7-159 Aviation (AVIM) deployed to Bosnia-Herzegovina in support of Operation Joint Endeavor/Operation Joint Guard for 8 months. In June of 1998 the Regimental Headquarters, 6-6 Cav and elements of 5-158 Aviation were again deployed to Bosnia-Herzegovina in support of Operations Joint Guard and Joint Forge for 5 months. The AH-64A's advanced sensors and sighting systems proved effective in removing the cover of darkness from anti-government forces.

Army National Guard units in North and South Carolina, Florida, Texas, Arizona, Utah and Idaho also fly Apache helicopters. The Army has fielded combat-ready AH-64A units in the United States, West Germany and in Korea, where they play a major role in achieving the US Army's security missions.

By late 1996, McDonnell Douglas Helicopters delivered 937 AH-64A Apaches -- 821 to the U.S. Army and 116 to international customers, including Egypt, Greece, Israel, Saudi Arabia and the United Arab Emirates.

The Apache is clearly one of the most dynamic and important programs in aviation and the Army, but it is not without limitations. Due to the possibility of surging the engines, pilots have been instructed not to fire rockets from in-board stations. According to current doctrine, they are to fire no more than pairs with two outboard launchers every three seconds, or fire with only one outboard launcher installed without restrictions (ripples permitted). These are the only conditions permitted. Other firing conditions will be required to be approved via a System Safety Risk Assessment (SSRA).

The improvement of aircraft systems troubleshooting is a high priority issue for O&S Cost reduction. Because of funding cuts, the level of contractor support to the field has been reduced. This results in higher costs in no fault found removals, maintenance man hours, and aircraft down time. The Apache PM, US Army Aviation Logistics School, and Boeing are currently undertaking several initiatives. Upgrading and improving the soldier's ability to quickly and accurately fault isolate the Apache weapons system is and will continue to be an O&S priority until all issues are resolved.

Prime Vendor Support (PVS) for the entire fleet of AH-64s is a pilot program for the Army, and may become a pilot program for the Department of Defense. PVS places virtually all of Apache's wholesale logistic responsibility under a single contract. The Apache flying hour program will provide upfront funding for spares, repairables, contractor technical experts, and reliability improvements. Starting at the flight line there will be contractor expert technicians with advanced troubleshooting capability assigned to each Apache Battalion. At the highest level, PVS represents a single contractor focal point for spares and repairs. The intent is to break the current budget and requirements cycle that has Apache at 67% supply availability with several thousand lines at zero balance.

Modernization Through Spares (MTS) is a spares/component improvement strategy applied throughout the acquisition life cycle and is based on technology insertion to enhance systems and extend useful life while reducing costs. The MTS initiative seeks to leverage current procurement funds and modernize individual system spares thereby incrementally improving these systems. MTS is accomplished via the "spares" acquisition process. MTS, a subset of acquisition reform, seeks to improve an end item's spare components. The emphasis is on form, fit and function, allowing a supplier greater design and manufacturing flexibility to exploit technology used in the commercial marketplace.

Apache MTS focuses on the insertion of the latest technology into the design and manufacture of select spares. This is to be accomplished without government research and development (R&D) funds, but rather, uses industry investment. Industry, in turn, recoups this investment through the sale of improved hardware via long term contracts.

Modernization efforts continue to improve the performance envelope of the AH-64A while reducing the cost of ownership. Major modernization efforts within the AH-64A fleet are funded and on schedule. GG Rotor modifications were finished in April 1998, and future improvements such as a Second Generation FLIR, a High Frequency Non-Line of Sight NOE radio, and an internal fully crashworthy auxiliary fuel tank are all on the verge of becoming a reality for the Apache.

The Aviation Mission Planning System (AMPS) and the Data Transfer Cartridge (DTC) are tools for the Embedded Global Positioning Inertial Navigation Unit (EGI) equipped AH-64A aircraft that allow aircrews to plan missions and download the information to a DTC installed in the Data Transfer Receptacle (DTR). This saves the pilots a lot of "fat fingering" and eliminates the worry of everyone being on the same "sheet of music". Other features of the DTC include; saving waypoints and targets and troubleshooting. The EGI program is a Tri-service program with the Army, Air Force and Navy.

The AH-64D Longbow Apache is a remanufactured and upgraded version of the AH-64A Apache attack helicopter. The primary modifications to the Apache are the addition of a millimeter-wave Fire Control Radar (FCR) target acquisition system, the

fire-and-forget Longbow Hellfire air-to-ground missile, updated T700-GE-701C engines, and a fully-integrated cockpit. In addition, the aircraft receives improved survivability, communications, and navigation capabilities. Most existing capabilities of the AH-64A Apache are retained.

Transportability requirements were initially identified in the ORD and further defined in the AH-64D System Specification. Both configurations of the AH-64D, including any removed items and appropriate PGSE, shall be capable of being transported aboard C-141B, C-5A, or C-17 aircraft. The aircraft shall also be capable of being transported and hangar stored below decks in the landing platform helicopter (LPH) type carrier, Fast SeaLift ships, Roll-on/Roll-off, LASH, SEABEE ships, and Military Sealift Command (MSC) dry cargo ships. Additionally, the aircraft shall be transportable by military M-270A1 trailer and commercial "Air-Ride" trailer or equivalent. For aerial recovery, the AH-64D with MMA will be externally transportable by CH-47D aircraft using the Unit Maintenance Aerial Recovery Kit. Two AH-64D plus one FCR aircraft will be transportable by C-141, six AH-64Ds (with a minimum of three FCR mission kits) are transportable by C-5, and three AH-64Ds and three FCR mission kits are transportable by C-17.

The AH-64D is being fielded in two configurations. The full-up AH-64D includes all of the improvements listed above. In addition, a version of the AH-64D without the FCR will be fielded. This version will not receive the new Radar Frequency Interferometer (RFI) or the improved engines, but will retain the other Longbow modifications. The AH-64D without FCR is capable of launching the Longbow Hellfire missile.

All AH-64A Apaches in the fleet are to be upgraded to the AH-64D configuration: 227 will be equipped with the FCR, and the remaining 531 will not. Each attack helicopter company will receive three aircraft with FCRs and five without.

McDonnell Douglas Helicopter Systems is under contract for the first 18 Longbow Apaches and delivered the first remanufactured Longbow Apache in March 1997. The Army and McDonnell Douglas agreed to a five-year, multi-year agreement that will give the Army 232 Longbow Apaches in the first five years of production. The multi-year purchase increases the Longbow Apache production rate in the first year to 24 aircraft and 232 for the five-year period. Under the multi-year contract, the Army will field two additional combat-ready Longbow Apache battalions. The contract also includes funding for McDonnell Douglas to train pilots and maintenance personnel for the first two equipped units, development of interactive electronic technical manuals, development of training devices, first article testing of the production aircraft, initial spares, and a variety of program support tasks for the first production lot. The U.S. Army plans to remanufacture its entire AH-64A Apache fleet of more than 750 aircraft over the next decade.

During Army operational testing in 1995, all six Longbow Apache prototypes

competed against standard AH-64A Apaches. The threat array developed to test the combat capabilities of the two Apache designs was a postulated 2004 lethal and digitized force consisting of heavy armor, air defense and countermeasures. The tests clearly demonstrated that Longbow Apaches:

Are 400 percent more lethal (hitting more targets) than the AH-64A, already the most capable and advanced armed helicopter in the world to enter service.

Are 720 percent more survivable than the AH-64A.

Meet or exceed Army requirements for both target engagement range and for probability of acquiring a selected target. The specific requirements and results are classified.

Easily can hit moving and stationary tanks on an obscured, dirty battlefield from a range of more than 7 kilometers, when optical systems are rendered ineffective.

Can use either its Target Acquisition Designation Sight or fire control radar as a targeting sight, offering increased battlefield flexibility.

Have the ability to initiate the radar scan, detect and classify more than 128 targets, prioritize the 16 most dangerous targets, transmit the information to other aircraft, and initiate a precision attack -- all in 30 seconds or less.

Require one third less maintenance man hours (3.4) per flight hour than the requirement.

Are able to fly 91 percent of the time -- 11 percent more than the requirement.

One issue uncovered during the Initial Operational Test that requires follow-on testing involves the method of employment of the Longbow Hellfire missile. During the force-on-force phase, Longbow flight crews frequently elected to override the system's automatic mode selection logic and fire missiles from a masked position. This powerful technique can significantly increase the helicopter's survivability, but has not been validated with live missile firings during developmental or operational testing. DOT&E is currently working with the Army to develop a test plan that will confirm system performance using this firing technique. This test program will include computer simulation of the missile's target acquisition and fly-out as well as live missile firings at moving armored vehicles.

With the addition of a new and highly sophisticated fire control radar (FCR), more commonly called the Longbow Fire Control Radar, the AH-64D has become the most advanced aerial fighting vehicle in the world. The FCR provides the Apache with the ability to detect, classify and prioritize stationary and moving targets both on the ground and in the air. With state of the art fire control, digital communications, automatic target classification and many other up to date features, the AH-64D Longbow Apache will dominate the battlefield for years to come.

The AH-64D Apache Longbow increases combat effectiveness over the AH-64A by providing a more flexible digital electronics architecture and integrating computer-based on-board Built-In Test Equipment (BITE), Automatic Test Equipment (ATE), and hard copy operator or Interactive Electronic Technical Manual (IETM) troubleshooting/maintenance manuals that will easily accommodate changes resulting from system growth. In addition, upgrades to electrical power and cooling systems and the expansion of the forward avionics bays to accommodate the installation of the FCR, and provide for

future growth. Navigation system accuracy is improved through integration of a miniaturized integrated Embedded Global Positioning System (GPS)/Inertial Navigation Unit (INU) (EGI), and an improved DOPPLER Velocity Rate Sensor (DVRS).

The fully integrated AH-64D without Longbow Mission Kit incorporates greater ordnance capability and flexibility than the AH-64A by utilizing the family of Semi-Active Laser (SAL) missiles (including the HELLFIRE II) and Longbow HELLFIRE RF Missile. The AH-64D without Longbow Mission Kit can operate in harmony with the FCR-equipped AH-64D and can accept a target hand over and fire the Longbow missile with minimum exposure to hostile forces.

The AN/APG-78 FCR is a multi-mode Millimeter Wave (MMW) sensor integrated on the Apache Longbow with the antenna and transmitter located above the aircraft main rotor head. It enhances Longbow system capabilities by providing rapid automatic detection, classification, and prioritization of multiple ground and air targets. The radar provides this capability in adverse weather and under battlefield obscurants. The FCR has four modes: (1) the Air Targeting Mode (ATM) which detects, classifies, and prioritizes fixed and rotary wing threats; (2) the Ground Targeting Mode (GTM) which detects, classifies, and prioritizes ground and air targets; (3) the Terrain Profiling Mode (TPM) which provides obstacle detection and adverse weather pilotage aids to the Longbow crew; (4) and the Built in Test (BIT) Mode which monitors radar performance in flight and isolates electronic failures before and during maintenance.

The Longbow RF missile and the Longbow HELLFIRE Launcher (LBHL) are referred to as the LBHMMS. The system incorporates a fire-and-forget missile that accepts primary and/or secondary targeting information from the FCR and single targeting information from TADS or another aircraft to acquire and engage targets. Similar to the FCR, the RF missile provides the capability to engage threats in adverse weather and through battlefield obscurants. Two acquisition modes, lock-on-before-launch (LOBL) and lock-on-after-launch (LOAL), allow engagement of ground and rotary wing threats at extended ranges. In the LOBL mode, the missile will acquire and track moving or short range stationary targets prior to leaving the launch platform. In the LOAL mode, the missile will acquire long range stationary targets shortly after leaving the launch platform.

The combination of the integrated FCR, LBHMMS and the Apache aircraft enhances battlefield awareness by providing coverage of the battle area at extended ranges, by reducing operational dependence on weather and battlefield conditions, and by rapid display of detected targets. It further improves the Longbow system's war fighting capability and survivability by providing rapid multi-target detection and engagement ability, navigational aids, and a fire-and-forget weapon delivery system.

The addition of the Longbow FCR provides a second and completely independent target acquisition sensor which may be operated by either crew member or combined to provide a degree of multi-sensor synergy. When operated independently, the pilot could

use the FCR to search for air targets in the ATM mode while the copilot/gunner (CPG) searches for ground targets using the Target Acquisition Designation Sight (TADS). Using both TADS and the FCR together combines the unique advantage of each sight. The rapid search, detection, classification, and prioritization of targets by the Longbow FCR can then be quickly and positively identified by using the electro-optics of TADS. The center of view can be focused on the location of the highest priority target and the CPG, at the touch of a switch, can view either display. Alternately, the FCR centerline can be cued to the TADS so that a rapid and narrow search could be made of a suspected target area.

The RFI is an integral part of the Longbow FCR. It has sensitivity over an RF spectrum to detect threat emitters when a threat radar is in a search and acquisition mode and also when the threat emitter is "looking" directly at and tracking the Longbow system. The RF band has been extended over that which was developed for the OH-58D Kiowa Warrior at the low end of the RF spectrum to detect newly identified air defense threats. The RFI has a programmable threat emitter library to allow additional threat signatures to be stored and/or updated.

The Materiel Fielding Plan (MFP) is essentially a one-stop reference for all fielding activity requirements. It shows who develops, fields, receives, and stores a piece of equipment and its associated tools, test equipment, repair parts, and training devices. The MFP will outline what the piece of equipment is used for, who uses it, who repairs it, the maintenance and supply structure which will be in place to provide life cycle support, and the training requirements inherent to the system. Several draft version MFPs are published per the documents listed above in order to generate a dialogue between the developer and the end user in order to simplify and expedite the fielding process.

The AH-64D Apache Longbow aircraft, Fire Control Radar (FCR), and Longbow Hellfire Modular Missile System (LBHMMS) were fielded starting with the 1-227 Attack Helicopter Battalion in July 1998. As this is a FORSCOM unit, the first MFP published will be for FORSCOM. Other MFPs, each tailored to the specific Major Command (MACOM) receiving the AH-64D, will be published at the appropriate time. Therefore, FORSCOM, TRADOC, USAREUR, EUSA, USAR, and the ARNG will each receive their own version of the MFP. Distribution varies with each subsequent draft prepared.

The Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) makes the decision as to what units receive the AH-64D and in what order. The AAH PMO publishes and distributes MFPs based on ODCSOPS' schedule. The fielding schedules change from time to time, and the schedule in the MFP is, therefore, current as of the publishing date. The First Draft for each MACOM's MFP is published approximately 26 months before the first aircraft and equipment are fielded to a MACOM. A MACOM's Final MFP is published approximately 8 months prior to its first-unit fielding. The fielding schedule as of 1 June 1997 is attached. It does not include the aircraft destined for the TRADOC training fleet at Ft. Rucker. Ft. Rucker begins receiving its AH-64Ds in June 1999.

APPENDIX D

AIRCRAFT RESEARCH DATA: C-17 GLOBEMASTER III

All references to quantitative and qualitative aircraft data in this appendix are from the Federation of American Scientists website unless otherwise noted with an appropriate parenthetical reference.

The C-17 is the newest transport aircraft in the United States Air Force's inventory entering service on 17 January 1995. The C-17 is capable of rapid strategic delivery of troops and all types of cargo to main operating bases or directly to forward bases in the deployment area. The aircraft is also able to perform theater airlift missions when required.

The C-17's system specifications impose a demanding set of reliability and maintainability requirements. These requirements include an aircraft mission completion success probability of 93 percent, only 18.6 aircraft maintenance manhours per flying hour, and full and partial mission capable rates of 74.7 and 82.5 percent respectively for a mature fleet with 100,000 flying hours.

The C-17 measures approximately 174 feet long with a 170-foot wingspan. The aircraft is powered by four fully reversible Pratt & Whitney F117-PW-100 engines (the commercial version is currently used on the Boeing 757). Each engine is rated at 40,900 pounds of thrust. The thrust reversers direct the flow of air upward and forward to avoid ingestion of dust and debris.

The aircraft is operated by a crew of three (pilot, copilot and loadmaster). Cargo is loaded onto the C-17 through a large aft door that accommodates military vehicles and palletized cargo. The C-17 can carry virtually all of the Army's air-transportable, outsized combat equipment. The C-17 is also able to airdrop paratroopers and cargo. Maximum payload capacity of the C-17 is 170,900 pounds, and its maximum gross takeoff weight is 585,000 pounds. With a payload of 130,000 pounds and an initial cruise altitude of 28,000 feet, the C-17 has an unrefueled range of approximately 5,200 nautical miles. Its cruise speed is approximately 450 knots (.77 Mach).

The design of this aircraft allows it to operate on small, austere airfields. The C-17 can take off and land on runways as short as 3,000 feet and as narrow as 90 feet wide. Even on such narrow runways, the C-17 can turn around by using its backing capability while performing a three-point star turn. Maximum use has been made of off-the-shelf and commercial equipment, including Air Force standardized avionics.

The C-17 made its maiden flight on Sept. 15, 1991. The aircraft is operated by the Air Mobility Command with initial operations at Charleston AFB, S.C., with the 437th

Airlift Wing and the 315th Airlift Wing (Air Force Reserve). The C-17 program is managed by the Aeronautical Systems Center, Wright-Patterson AFB, Ohio.

Based on a buy of 120 aircraft, the last C-17 delivery was to be in November, 2004. It is now May, 2005 and the last aircraft has not been delivered. The original specification from McDonnell Douglas defined a service life of 30,000 hours. Modification programs will keep the aircraft in line with current and future requirements for threat avoidance, navigation, communications, and enhanced capabilities. These modifications should include global air traffic management (GATM) and automatic dependent surveillance to meet anticipated navigation requirements. Commercially available avionics and mission computer upgrades are being investigated to reduce life-cycle costs and improve performance. Also, upgraded communication systems to enhance worldwide voice and data (including secure) transmission will support command and control.

APPENDIX E

AIRCRAFT RESEARCH DATA: F-16 FIGHTING FALCON

All references to quantitative and qualitative aircraft data in this appendix are from the Federation of American Scientists website unless otherwise noted with an appropriate parenthetical reference.

Genesis of the successful F-16 fighter/attack aircraft lies in reaction to severe deficiencies in US fighter design revealed by the Vietnam War. Following the success of the small, highly maneuverable F-86 day fighter in the Korean War, US fighter design changed to emphasize maximum speed, altitude, and radar capability at the expense of maneuverability, pilot vision, and other attributes needed for close combat. This trend reached its extremity in the McDonnell Douglas F-4 Phantom, which was the principal fighter for both the US Air Force and Navy during the latter part of the Vietnam War.

The F-4 was originally designed as an interceptor for defense of the fleet against air attack - a mission neither it nor any other jet has ever executed, because no US fleet has come under air attack since the beginning of the jet age. Be that as it may, the F-4 interceptor was designed to meet the fleet defense mission by using rapid climb to high altitude, high supersonic speed, and radar-guided missiles to shoot down threat aircraft at long distance.

Used as a fighter rather than as an interceptor in Vietnam, the F-4 was severely miscast. Against very inferior North Vietnamese pilots flying small, highly maneuverable MiG-21s, the air-to-air kill ratio sometimes dropped as low as 2 to 1, where it had been 13 to 1 in Korea. As the Vietnam War drew to a close, it was generally agreed that the F-4 had prohibitive deficiencies including:

LARGENESS. F-4 pilots too frequently found themselves fighting at separation distances at which they could not see the smaller MiG-21s, but the MiG-21 pilots could see them.

POOR PILOT VISION. In order to minimize high-speed drag, the F-4, and all combat aircraft before the F-14, does not have a bubble canopy. It is designed for a pilot to look straight ahead. Vision down and to the sides is poor; vision to the rear is nonexistent.

MANEUVERABILITY. While the F-4 can pull 7G in turns, which was acceptable for that time, it can only do so by rapidly bleeding off energy (losing speed and/or altitude).

TRANSIENT PERFORMANCE. Ability of the F-4 to change its maneuver (that is, to roll rapidly while pulling high Gs) was poor.

COST. The large F-4 was an expensive aircraft to procure and maintain. This meant that, compared to the MiG-21, fewer aircraft could be bought with a given budget.

NO GUN. The F-4 was designed without a gun, and was thus not capable of very close combat.

COMBAT PERSISTENCE. While the ferry range of the F-4 was acceptable, its ability to engage in sustained hard maneuvering without running out of fuel was a significant problem.

These various sacrifices were rationalized by the belief that visual dogfighting was obsolete, and that in the supersonic age, air combat would be fought beyond visual range (BVR) using radar-guided missiles. This concept failed in Vietnam for two reasons: First, radar could detect and track aircraft but not identify them. Operating beyond visual range created an unacceptable risk of shooting down one's own aircraft. Pilots were therefore required to close to visually identify the target before shooting; this eliminated the theoretical range advantage of radar-guided missiles. Second, the performance of the Sparrow radar-guided missile in Vietnam was poor, generally yielding less than 10% kill per shot.

Dissatisfaction with these deficiencies led to the US Air Force F-15 and US Navy F-14 designs. On this page we discuss only the Air Force programs.

The original F-15 had excellent pilot vision, including being able to see 360 degrees in the horizontal plane. It had strong high-speed maneuverability and a 20mm cannon. In addition to rectifying some of the F-4's deficiencies, it could fly higher and faster than the F-4, and had dramatically better climb and acceleration.

It also had powerful radar with advanced look-down shoot-down capability, and relied on the Sparrow missile as its principal weapon.

Nevertheless, an informal but influential group called the "Fighter Mafia" objected to the F-15 as moving in the wrong direction. (The most prominent Fighter Mafia spokesmen were systems analyst Pierre Sprey, test pilot Charles E. Meyers, and legendary fighter pilot John Boyd.)

The F-15, the Fighter Mafia objected, was even larger and more expensive than the F-4. Much of that money went into creating high maximum speed (Mach 2.5) and altitude (65,000 feet) and to serving as a launcher, under BVR conditions which couldn't be used in real combat. While recognizing that the F-15 had phenomenal supersonic climb and maneuverability (it could sustain 6Gs at Mach 1.6), at such speeds it could not fight because its turn radius was so large that it could not keep the enemy in sight.

What the Air Force needed, the Mafia argued, was a successor to the WWII P-51 Mustang and the Korean War F-86 Saber: an all-new small fighter that would be cheap enough to buy in large numbers. (The F-104 was not considered a predecessor aircraft because, while it had excellent climb and acceleration, its wings were too small, leaving it deficient in range and maneuverability.) The new fighter would have revolutionary maneuverability, transient performance, acceleration, and climb at the subsonic and transonic speeds at which air combat is actually fought. It would have a gun and its primary armament would be the infra-red guided Sidewinder missile that had proven highly effective in Vietnam.

While Sidewinder's range was limited to about three miles, the Mafia argued that air combat beyond that range was fantasy in any case. Some members of the Mafia even

suggested that the ideal small fighter would have no radar at all, although this was a minority view.

In any case, the Air Force establishment wanted no part of a new small fighter, with or without radar. It was regarded as a threat to the F-15, which was USAF's highest priority program. But the Fighter Mafia gained considerable resonance in Congress and within the Office of the Secretary of Defense. In 1971 Deputy Secretary of Defense David Packard began a Lightweight Fighter (LWF) program to explore the concept.

The LWF was to be about 20,000 pounds, or half the weight of the F-15, and was to stress low cost, small size, and very high performance at speed below Mach 1.6 and altitude below 40,000 feet. Two competing designs would be chosen for prototyping.

Industry recognized, correctly, that regardless of USAF hostility, LWF variants had great potential for profitable foreign military sales, including replacing the F-104. Single-engine designs were put forward by Boeing, General Dynamics, LTV, Northrop, and Rockwell. Northrop also proposed on a twin-engine design, in effect using Air Force money to develop a replacement for its F-5 export fighter.

The Boeing and General Dynamics designs were the clear leaders from the beginning, with the Northrop twin-engine design clearly the weakest of the six.

But midway through this stage of the competition, some potential foreign buyers expressed concern over buying a new single-engine fighter. The previous single-engine supersonic export fighter, the F-104, had a troublesome safety record that some buyers were disinclined to repeat.

USAF, therefore, decided that one of the two down-selectees had to have two engines. Since the last-place Northrop design was the only twin-engine contender, it became a down-selection winner by default.

When the General Dynamics design was chosen the other selectee on merit, Boeing was no doubt a bit miffed that its loss was caused by USAF changing the rules in mid-competition. But it did not protest the decision.

Of the two surviving designs, now designated the General Dynamics YF-16 and the Northrop YF-17, the YF-17 was a relatively conventional design, to some extent an outgrowth of the F-5, while the YF-16 was an all-new design incorporating highly innovative technologies that in many respects reached beyond those of the more expensive F-15. These included:

FLY BY WIRE. From the outset, the YF-16 had no direct connection between the pilot's controls and the aircraft's control surfaces. Instead, the stick and rudder controls were connected to quadruple-redundant computers, which then told the elevators, ailerons, and rudder what to do. This had several large advantages over previous systems. It was quicker responding, automatically correcting for gusts and thermals with no effort from

the pilot. It could be programmed to compensate for aerodynamic problems and fly like an ideal airplane. Most importantly, it enabled, with full safety, a highly efficient unstable design.

NEGATIVE STABILITY. All previous aircraft designs had been aerodynamically stable. That is, the center of gravity was well in front of the center of lift and the center of pressure (drag).

To illustrate the difference between stable and unstable designs, take a sheet of cardboard and, holding it by the leading edge, pull it rapidly through the air. It will stretch out behind your hand in a stable manner. This is a stable design. Now take it by the trailing edge and push forward from there. It will immediately flip up or down uncontrollably. That is an unstable design.

The downside of aerodynamic stability is that the aircraft is nose-heavy and always trying to nose down. The elevator must therefore push the tail down to level the airplane. But in addition to rotating the airplane from nose-down to level, the elevator is exerting negative lift; that is, it is pushing the airplane down. In order to counteract this negative lift, the wing needs to be made larger to create more positive lift. This increases both weight and drag, decreasing aircraft performance. In pitch-up situations including hard turns which are the bread and butter of aerial combat, this negative effect is greatly magnified.

The YF-16 became the world's first aircraft to be aerodynamically unstable by design. With its rearward center of gravity, its natural tendency is to nose up rather than down. So level flight is created by the elevator pushing the tail up rather than down, and therefore pushing the entire aircraft up. With the elevator working with the wing rather than against it, wing area, weight, and drag are reduced. The airplane was constantly on the verge of flipping up or down totally out of control, and this tendency was being constantly caught and corrected by the fly-by-wire control system so quickly that neither the pilot nor an outside observer could know anything was happening. If the control system were to fail, the aircraft would instantly disintegrate; however, this has never happened.

HIGH G LOADS. Previous fighters were designed to take 7Gs, mainly because it was believed that the human pilot, even with a G-suit, could not handle more. The YF-16 seatback was reclined 30 degrees, rather than the usual 13 degrees. This was to increase the ability of the pilot to achieve 9Gs by reducing the vertical distance between head and heart. Additionally, the traditional center control stick was replaced by a stick on the right side, with an armrest to relieve the pilot of the need to support his arm when it weighed nine times normal.

PILOT VISION. In addition to allowing full-circle horizontal vision and unprecedented vision over the sides, the YF-16 canopy was designed without bows in the forward hemisphere.

GROWTH PREVENTION. Traditionally, room for growth has been considered an asset. Fighter aircraft have averaged weight gain of about one pound per day as new capabilities are added, cost increases, and performance declines. The F-15, for example, was designed with about 15 cubic feet of empty space to allow for future installation of additional equipment. In a radical departure, the YF-16 was intentionally designed with very little empty space, (about two cubic feet), with the explicit intention of preventing growth. One member of the House Armed Services Committee actually wrote to the

Secretary of the Air Force asking that the F-16's empty space be filled with Styrofoam to insure that "gold-plated junk" was not added to the design.

COMBAT RADIUS AND PERSISTENCE. General Dynamics chose a single turbofan engine, essentially the same engine as one of the two that powered the F-15. Use of a single engine helped minimize weight and drag; use of a turbofan rather than a pure jet engine gave high fuel efficiency. Additionally, the YF-16 designers used a "blended body" design in which the wing gradually thickened at the root and blended into the body contours without the usual visible joint. The space thus created was filled with fuel. With such a high fuel fraction and a fuel-efficient engine, the YF-16 was able to break the presumption that small aircraft were necessarily short-ranged.

RADAR INTEGRATION. Because the YF-16 carried no radar-guided missiles, it could only fight within visual range. Moreover, the small weight and space available limited the range of its radar. Nevertheless, it was given a technologically advanced small radar, with excellent look-down capability. Most importantly, the radar was integrated with the visual combat mode. That is, the radar projected an image of the target aircraft onto the Heads Up Display so that, by looking at that image, the pilot was looking exactly where the target would become visible as he approached it.

The competing Northrop YF-17 design was somewhat larger than the YF-16, and used two smaller pure jet engines. At the price of reduced range and persistence, the YF-17 avoided the main problem of the YF-16's turbofan: the inertia of the large fan required too long - in some cases six seconds - to spool up from idle to full power. In other respects, the YF-17 progressed better than expected, given its initial last place position.

Northrop argued that its twin-engine design added an essential safety factor, citing its experience with the small twin-engine F-5 fighter as an example. USAF did not find this persuasive, in part because a two engine plane with one engine out is useless in combat, and the probability of an engine failure was nominally twice as high with two engines as with one. The higher performance, better transient maneuverability, longer range, and lower cost of the YF-16 carried the day, and in 1976 the F-16 was chosen over the F-17.

USAF was then in the uncomfortable position of having a lightweight fighter design that could outmaneuver and outrange its pride and joy, the F-15 air superiority fighter. In real-world combat conditions, which meant Mach 1.2 or below, the F-16s held a significant edge over the F-15. To some extent this problem was solved by designating the F-16 as a "swing fighter" to do both air-to-air and air-to-ground, while the F-15 was to continue its aristocratic mission of pure air-to-air.

Probably the F-16's greatest asset during development was its unpopularity with the USAF establishment. Knowing that their airplane was in constant threat of cancellation, the General Dynamics designers were inspired to do everything possible and then some to maintain performance and prevent cost growth. For example, while the F-15 was about 25% titanium, titanium in the F-16 was limited to 2%. As another example, a fixed engine inlet was used to hold down cost, even though a variable inlet would have given better performance above Mach 1.5.

The F-16 has been, by any standard, a success. USAF has used it heavily and successfully for air-to-ground in the 1991 Gulf war and all subsequent conflicts. The Israeli Air Force has also had great success with it.

With the benefit of hindsight, it is worthwhile to look back from the current (2003) vantage point to see how the original concept has fared.

FLY BY WIRE has been a clear success. It is now used in essentially all military fixed wing aircraft and on many commercial aircraft.

NEGATIVE STABILITY, or at least reduced positive stability, has worked without a failure - no F-16s have disintegrated in air from control system failure - and is coming into increasing use.

HIGH G LOADS. The 9G standard pioneered by the F-16 is now universal for new fighter designs, although it is achieved more by pilot training than by hardware. Benefit of the 30-degree reclining seat back has not been clearly established, and many pilots find it increases the difficulty of checking their six o'clock position while in hard maneuvers. So more recent designs have not copied the F-16 seat. Similarly, the side stick has worked well but has not proven as essential as its designers originally expected. One enduring controversy is whether control systems should, as is the case with the F-16, be programmed to unconditionally limit the aircraft to 9gs, or whether higher loads should be permitted in emergencies. One eminent General Dynamics test pilot, a "super pilot" who in his fifties was still able to sustain 9Gs for 45 seconds, published an article on the subject in "Code One", the General Dynamics house organ, arguing that there was not enough useful benefit in being able to exceed 9 Gs to justify the strain on the airframe, particularly since few pilots could retain functionality above 9Gs. Tragically and ironically, this pilot was killed when his plane, pulling 9Gs in a hard maneuver, was unable to pull up enough to avoid impacting the ground. This outstanding pilot might have been able to function with a brief application of 10, 11, or even 12Gs. Could that have saved him and his aircraft? Could it save others in the future?

PILOT VISION. Pilots like the F-16 canopy without front bows for its quietness as well as its vision. One drawback is that in order to avoid optical distortion in the bowless design, the conventional use of thick polycarbonate on the front to protect against birdstrike, and thinner polycarbonate for the rest of the canopy, cannot be used. Because the F-16 canopy uses thick polycarbonate throughout, it is not possible to eject by using the seat to puncture through the canopy. The canopy must first be blown off by small rockets, prolonging the ejection sequence slightly. On balance, the F-16 canopy concept is considered successful and it is continued in the F-22. On the other hand, neither Joint Strike Fighter candidate used full-circle vision, much less a bowless canopy.

GROWTH PREVENTION. The original concept of a small day air-to-air fighter was lost before the first production aircraft. The fuselage was extended so that the single-seat versions became as long as the two-seat version and air-to-ground capability was added. As its life progressed, the F-16 became progressively larger and heavier as more capability, including the AMRAAM radar-guided missile, chaff and flare dispensers, and more hard points were added. Still, weight gain has been only about half the traditional pound per day, so the determination of the original designers has not been in vain.

COMBAT RADIUS AND PERSISTENCE. The F-16 blended body has worked well, but has not been emulated in most newer designs.

RADAR INTEGRATION. Integration of radar with visual systems has been fully successful and is now standard fighter design.

In January 1972, the Lightweight Fighter Program solicited design specifications from several American manufacturers. Participants were told to tailor their specifications toward the goal of developing a true air superiority lightweight fighter. General Dynamics and Northrop were asked to build prototypes, which could be evaluated with no promise of a follow-on production contract. These were to be strictly technology demonstrators. The two contractors were given creative freedom to build their own vision of a lightweight air superiority fighter, with only a limited number of specified performance goals. Northrop produced the twin-engine YF-17, using breakthrough aerodynamic technologies and two high-thrust engines. General Dynamics countered with the compact YF-16, built around a single F100 engine.

When the Lightweight Fighter competition was completed early in 1975, both the YF-16 and the YF-17 showed great promise. The two prototypes performed so well, in fact, that both were selected for military service. On 13 January 1975 the Air Force announced that the YF-16's performance had made it the winner of its Air Combat Fighter (ACF) competition. This marked a shift from the original intention to use the two airplanes strictly as technology demonstrators. General Dynamics' YF-16 had generally shown superior performance over its rival from Northrop. At the same time, the shark-like fighter was judged to have production costs lower than expected, both for initial procurement and over the life cycle of the plane. At the same time, the YF-16 had proved the usefulness not only of fly-by-wire flight controls, but also such innovations as reclined seat backs and transparent head-up display (HUD) panels to facilitate high-G maneuvering, and the use of high profile, one-piece canopies to give pilots greater visibility. Thus, the Air Force had its lightweight fighter, the F-16.

The original F-16 was designed as a lightweight air-to-air day fighter. Air-to-ground responsibilities transformed the first production F-16s into multirole fighters. The empty weight of the Block 10 F-16A is 15,600 pounds. The empty weight of the Block 50 is 19,200 pounds. The A in F-16A refers to a Block 1 through 20 single-seat aircraft. The B in F-16B refers to the two-seat version. The letters C and D were substituted for A and B, respectively, beginning with Block 25. Block is an important term in tracing the F-16's evolution. Basically, a block is a numerical milestone. The block number increases whenever a new production configuration for the F-16 is established. Not all F-16s within a given block are the same. They fall into a number of block subsets called miniblocks. These sub-block sets are denoted by capital letters following the block number (Block 15S, for example). From Block 30/32 on, a major block designation ending in 0 signifies a General Electric engine; one ending in 2 signifies a Pratt & Whitney engine.

The **F-16A**, a single-seat model, first flew in December 1976. The first operational F-16A was delivered in January 1979 to the 388th Tactical Fighter Wing at Hill Air Force Base, Utah. The F-16B, a two-seat model, has tandem cockpits that are

about the same size as the one in the A model. Its bubble canopy extends to cover the second cockpit. To make room for the second cockpit, the forward fuselage fuel tank and avionics growth space were reduced. During training, the forward cockpit is used by a student pilot with an instructor pilot in the rear cockpit.

Block 1 and Block 5 F-16s were manufactured through 1981 for USAF and for four European air forces. Most Blocks 1 and 5 aircraft were upgraded to a Block 10 standard in a program called Pacer Loft in 1982.

Block 10 aircraft (312 total) were built through 1980. The differences between these early F-16 versions are relatively minor.

Block 15 aircraft represent the most numerous version of the more than 3,600 F-16s manufactured to date. The transition from Block 10 to Block 15 resulted in two hardpoints added to the chin of the inlet. The larger horizontal tails, which grew in area by about thirty percent are the most noticeable difference between Block 15 and previous F-16 versions.

The **F-16C and F-16D** aircraft, which are the single- and two-place counterparts to the F-16A/B, incorporate the latest cockpit control and display technology. All F-16s delivered since November 1981 have built-in structural and wiring provisions and systems architecture that permit expansion of the multirole flexibility to perform precision strike, night attack and beyond-visual-range interception missions. All active units and many Air National Guard and Air Force Reserve units have converted to the F-16C/D, which is deployed in a number of Block variants.

Block 25 added the ability to carry AMRAAM to the F-16 as well as night/precision ground-attack capabilities, as well as an improved radar, the Westinghouse (now Northrop-Grumman) AN/APG-68, with increased range, better resolution, and more operating modes.

Block 30/32 added two new engines -- Block 30 designates a General Electric F110-GE-100 engine, and Block 32 designates a Pratt & Whitney F100-PW-220 engine. Block 30/32 can carry the AGM-45 Shrike and the AGM-88A HARM, and like the Block 25, it can carry the AGM-65 Maverick.

Block 40/42 - F-16CG/DG - gained capabilities for navigation and precision attack in all weather conditions and at night with the LANTIRN pods and more extensive air-to-ground loads, including the GBU-10, GBU-12, GBU-24 Paveway laser-guided bombs and the GBU-15. Block 40/42 production began in 1988 and ran through 1995. Currently, the Block 40s are being upgraded with several Block 50 systems: ALR-56M threat warning system, the ALE-47 advanced chaff/flare dispenser, an improved performance battery, and Falcon UP structural upgrade.

Block 50/52 Equipped with a Northrop Grumman APG-68(V)7 radar and a General Electric F110-GE-129 Increased Performance Engine, the aircraft are also capable of using the Lockheed Martin low-altitude navigation and targeting for night (LANTIRN) system. Technology enhancements include color multifunctional displays and programmable display generator, a new Modular Mission Computer, a Digital Terrain System, a new color video camera and color triple-deck video recorder to record the pilot's head-up display view, and an upgraded data transfer unit. In May 2000, the Air Force certified Block 50/52 [aka Block 50 Plus] F-16s to carry the CBU-103/104/105 Wind-Corrected Munitions Dispenser, the AGM-154 Joint Stand-Off Weapon, the GBU-

31/32 Joint Direct Attack Munition, and the Theater Airborne Reconnaissance System. Beginning in mid-2000, Lockheed-Martin began to deliver Block 50/52 variants equipped with an on-board oxygen generation system (OBOGS) designed to replace the obsolete, original LOX system.

Block 50D/52D *Wild Weasel* F-16CJ (CJ means block 50) comes in C-Model (1 seat) and D-Model (2 seat) versions. It is best recognized for its ability to carry the AGM-88 HARM and the AN/ASQ-213 HARM Targeting System (HTS) in the suppression of enemy air defenses [SEAD] mission. The HTS allows HARM to be employed in the range-known mode providing longer range shots with greater target specificity. This specialized version of the F-16, which can also carry the ALQ-119 Electronic Jamming Pod for self protection, became the sole provider for Air Force SEAD missions when the F-4G Wild Weasel was retired from the Air Force inventory. The lethal SEAD mission now rests solely on the shoulders of the F-16 HARM Targeting System. Although F-18s and EA-6Bs are HARM capable, the F-16 provides the ability to use the HARM in its most effective mode. The original concept called for teaming the F-15 Precision Direction Finding (PDF) and the F-16 HTS. Because this teaming concept is no longer feasible, the current approach calls for the improvement of the HTS capability. The improvement will come from the Joint Emitter Targeting System (JETS), which facilitates the use of HARM's most effective mode when launched from any JETS capable aircraft.

Block 60 - In May 1998 the UAE announced selection of the Block 60 F-16 to be delivered between 2002-2004. The upgrade package consists of a range of modern systems including conformal fuel tanks for greater range, new cockpit displays, an internal sensor suite, a new mission computer and other advanced features including a new agile beam radar.

The Common Configuration Implementation Program (CCIP) for the USAF's F-16C/D fleet provides significant avionics upgrades to Block 40 and 50 F-16s, ensuring their state-of-the-art capability well into the 21st century. A key element of the upgrade is a common hardware and software avionics configuration for these two blocks that will bring together the Block 40/42 and 50/52 versions into a common configuration of core avionics and software. The avionics changes consist of the following systems: Link 16 Multifunctional Information Distribution System (MIDS), Joint Helmet-Mounted Cueing System (JHMCS), commercial expanded programmable display generator, color multifunction display set, modular mission computer, mux loadable data entry display set and an electronic horizontal situation display. This package contains a number of systems being incorporated into European F-16s in the F-16A/B Mid-Life Update program. The first aircraft upgraded under CCIP were delivered to combat units in December 2001 (1).

The Air Force will soon be flying only Block 40/42 and Block 50/52 F-16s in its active-duty units. Block 25 and Block 30/32 will be concentrated in Air National Guard and Air Force Reserve units.

Service Life

The *Falcon Up* Structural Improvement Program program incorporates several major structural modifications into one overall program, affecting all USAF F-16s. Falcon Up will allow Block 25/30/32 aircraft to meet a 6000 hour service life, and allow Block 40/42 aircraft to meet an 8000 hour service life.

In view of the challenges inherent in operating F-16s to 8,000 flight hours, together with the moderate risk involved in JSF integration, the Department has established a program to earmark by FY 2000 some 200 older, Block 15 F-16 fighter aircraft in inactive storage for potential reactivation. The purpose of this program is to provide a basis for constituting two combat wings more quickly than would be possible through new production. This force could offset aircraft withdrawn for unanticipated structural repairs or compensate for delays in the JSF program. Reactivating older F-16s is not a preferred course of action, but represents a relatively low-cost hedge against such occurrences.

APPENDIX F

AIRCRAFT RESEARCH DATA: F-22 RAPTOR

All references to quantitative and qualitative aircraft data in this appendix are from the Federation of American Scientists website unless otherwise noted with an appropriate parenthetical reference.

The F-22 program is developing the next-generation air superiority fighter for the Air Force to counter emerging worldwide threats. It is designed to penetrate enemy airspace and achieve a first-look, first-kill capability against multiple targets. The F-22 is characterized by a low-observable, highly maneuverable airframe; advanced integrated avionics; and aerodynamic performance allowing supersonic cruise without afterburner.

Stealth: Greatly increases survivability and lethality by denying the enemy critical information required to successfully attack the F-22

Integrated Avionics: Allows F-22 pilots unprecedented awareness of enemy forces through the fusion of on- and off-board information

Supercruise: Enhances weapons effectiveness; allows rapid transit through the battlespace; reduces the enemy's time to counter attack

The F-22's engine is expected to be the first to provide the ability to fly faster than the speed of sound for an extended period of time without the high fuel consumption characteristic of aircraft that use afterburners to achieve supersonic speeds. It is expected to provide high performance and high fuel efficiency at slower speeds as well.

For its primary air-to-air role, the F-22 will carry six AIM-120C and two AIM-9 missiles. For its air-to-ground role, the F-22 can internally carry two 1,000 pound-class Joint Direct Attack Munitions (JDAM), two AIM-120C, and two AIM-9 missiles. With the Global Positioning System-guided JDAM, the F-22 will have an adverse weather capability to supplement the F-117 (and later the Joint Strike Fighter) for air-to-ground missions after achieving air dominance.

The F-22's combat configuration is "clean," that is, with all armament carried internally and with no external stores. This is an important factor in the F-22's stealth characteristics, and it improves the fighter's aerodynamics by dramatically reducing drag, which, in turn, improves the F-22's range. The F-22 has four under wing hardpoints, each capable of carrying 5,000 pounds. A single pylon design, which features forward and aft sway braces, an aft pivot, electrical connections, and fuel and air connections, is used. Either a 600-gallon fuel tank or two LAU-128/A missile launchers can be attached to the bottom of the pylon, depending on the mission. There are two basic external configurations for the F-22:

Four 600 gallon fuel tanks, no external weapons: This configuration is used when the aircraft is being ferried and extra range is needed. A BRU-47/A rack is used on each pylon to hold the external tanks.

Two 600 gallon fuel tanks, four missiles: This configuration is used after air dominance in a battle area has been secured, and extra loiter time and firepower is required for Combat Air Patrol (CAP). The external fuel tanks, held by a BRU-47/A rack are carried on the inboard stations, while a pylon fitted with two LAU-128/A rail launchers is fitted to each of the outboard stations.

An all-missile external loadout (two missiles on each of the stations) is possible and would not be difficult technically to integrate, but the Air Force has not stated a requirement for this configuration. Prior to its selection as winner of what was then known as the Advanced Tactical Fighter (ATF) competition, the F-22 team conducted a 54-month demonstration/ validation (dem/val) program. The effort involved the design, construction and flight testing of two YF-22 prototype aircraft. Two prototype engines, the Pratt & Whitney YF119 and General Electric YF120, also were developed and tested during the program. The dem/val program was completed in December 1990. Much of that work was performed at Boeing in Seattle, Lockheed (now known as Lockheed Martin) facilities in Burbank, Calif., and at General Dynamics' Fort Worth, Texas, facilities (now known as Lockheed Martin Tactical Aircraft Systems). The prototypes were assembled in Lockheed's Palmdale, Calif., facility and made their maiden flight from there. Since that time Lockheed's program management and aircraft assembly operations have moved to Marietta, Ga., for the EMD and production phases.

The F-22 passed milestone II in 1991. At that time, the Air Force planned to acquire 648 F-22 operational aircraft at a cost of \$86.6 billion. After the Bottom Up Review, completed by DOD in September 1993, the planned quantity of F-22s was reduced to 442 at an estimated cost of \$71.6 billion.

A \$9.55 billion contract for Engineering and Manufacturing Development (EMD) of the F-22 was awarded to the industry team of Boeing and Lockheed Martin in August 1991. Contract changes since then have elevated the contract value to approximately \$11 billion. Under terms of the contract, the F-22 team will complete the design of the aircraft, produce production tooling for the program, and build and test nine flightworthy and two ground-test aircraft.

A Joint Estimate Team was chartered in June 1996 to review the F-22 program cost and schedule. JET concluded that the F-22 engineering and manufacturing development program would require additional time and funding to reduce risk before the F-22 enters production. JET estimated that the development cost would increase by about \$1.45 billion. Also, JET concluded that F-22 production cost could grow by about \$13 billion (from \$48 billion to \$61 billion) unless offset by various cost avoidance actions. As a result of the JET review the program was restructured, requiring an additional \$2.2 billion be added to the EMD budget and 12 months be added to the schedule to ensure the achievement of a producible, affordable design prior to entering production. The program restructure allowed sourcing within F-22 program funds by deleting the three pre-production aircraft and slowing the production ramp. Potential for cost growth in production was contained within current budget estimate through cost reduction initiatives formalized in a government/industry memorandum of agreement. The Defense

Acquisition Board principals reviewed the restructured program strategy and on February 11, 1997 the Defense Acquisition Executive issued an Acquisition Defense Memorandum approving the strategy.

The Quadrennial Defense Review report, which was released in mid-May 1997, reduced the F-22 overall production quantity from 438 to 339, slowed the Low Rate Initial Production ramp from 70 to 58, and reduced the maximum production rate from 48 to 36 aircraft per year.

The F-22 EMD program marked a successful first flight on September 7, 1997. The flight test program, which has already begun in Marietta, Georgia, will continue at Edwards AFB, California through the year 2001. Low rate production is scheduled to begin in FY99. The aircraft production rate will gradually increase to 36 aircraft per year in FY 2004, and will continue that rate until all 339 aircraft have been built (projected to be complete in 2013). Initial Operational Capability of one operational squadron is slated for December 2005.

The F-15 fleet is experiencing problems with avionics parts obsolescence, and the average age of the fleet will be more than 30 years when the last F-22 is delivered in 2013. But the current inventory of F-15s can be economically maintained in a structurally sound condition until 2015 or later. None of the 918 F-15s that were in the inventory in July 1992 will begin to exceed their expected economic service lives until 2014.

APPENDIX G

AIRCRAFT RESEARCH DATA: F-35 JOINT STRIKE FIGHTER

All references to quantitative and qualitative aircraft data in this appendix are from the Federation of American Scientists website unless otherwise noted with an appropriate parenthetical reference.

The Joint Strike Fighter (JSF) is a multi-role fighter optimized for the air-to-ground role, designed to affordably meet the needs of the Air Force, Navy, Marine Corps and allies, with improved survivability, precision engagement capability, the mobility necessary for future joint operations and the reduced life cycle costs associated with tomorrow's fiscal environment. JSF will benefit from many of the same technologies developed for F-22 and will capitalize on commonality and modularity to maximize affordability.

The 1993 Bottom-Up Review (BUR) determined that a separate tactical aviation modernization program by each Service was not affordable and canceled the Multi-Role Fighter (MRF) and Advanced Strike Aircraft (A/F-X) program. Acknowledging the need for the capability these canceled programs were to provide, the BUR initiated the Joint Advanced Strike Technology (JAST) effort to create the building blocks for affordable development of the next-generation strike weapons system. After a review of the program in August 1995, DOD dropped the "T" in the JAST program and the JSF program has emerged from the JAST effort. Fiscal Year 1995 legislation merged the Defense Advanced Research Projects Agency (DARPA) Advanced Short Take-off and Vertical Landing (ASTOVL) program with the JSF Program. This action drew the United Kingdom (UK) Royal Navy into the program, extending a collaboration begun under the DARPA ASTOVL program.

The JSF program will demonstrate two competing weapon system concepts for a tri-service family of aircraft to affordably meet these service needs:

USAF-Multi-role aircraft (primarily air-to-ground) to replace F-16 and A-10 and to complement F-22. The Air Force JSF variant poses the smallest relative engineering challenge. The aircraft has no hover criteria to satisfy, and the characteristics and handling qualities associated with carrier operations do not come into play. As the biggest customer for the JSF, the service will not accept a multirole F-16 fighter replacement that doesn't significantly improve on the original.

USN-Multi-role, stealthy strike fighter to complement F/A-18E/F. Carrier operations account for most of the differences between the Navy version and the other JSF variants. The aircraft has larger wing and tail control surfaces to better manage low-speed approaches. The internal structure of

the Navy variant is strengthened up to handle the loads associated with catapult launches and arrested landings. The aircraft has a carrier-suitable tailhook. Its landing gear has a longer stroke and higher load capacity. The aircraft has almost twice the range of an F-18C on internal fuel. The design is also optimized for survivability.

USMC-Multi-role Short Take-Off & Vertical Landing (STOVL) strike fighter to replace AV-8B and F/A-18A/C/D. The Marine variant distinguishes itself from the other variants with its short takeoff/vertical landing capability.

UK-STOVL (supersonic) aircraft to replace the Sea Harrier. Britain's Royal Navy JSF will be very similar to the U.S. Marine variant.

The JSF concept is building these three highly common variants on the same production line using flexible manufacturing technology. Cost benefits result from using a flexible manufacturing approach and common subsystems to gain economies of scale. Cost commonality is projected in the range of 70-90 percent; parts commonality will be lower, but emphasis is on commonality in the higher-priced parts. Key design goals of the JSF system include:

Survivability: radio frequency/infrared signature reduction and on-board countermeasures to survive in the future battlefield--leveraging off F-22 air superiority mission support

Lethality: integration of on- and off-board sensors to enhance delivery of current and future precision weapons

Supportability: reduced logistics footprint and increased sortie generation rate to provide more combat power earlier in theater

Affordability: focus on reducing cost of developing, procuring and owning JSF to provide adequate force structure

JSF's integrated avionics and stealth are intended to allow it to penetrate surface-to-air missile defenses to destroy targets, when enabled by the F-22's air dominance. The JSF is designed to complement a force structure that includes other stealthy and non-stealthy fighters, bombers, and reconnaissance / surveillance assets.

JSF requirements definition efforts are based on the principles of Cost as an Independent Variable. Early interaction between the warfighter and developer ensures cost / performance trades are made early, when they can most influence weapon system cost. The Joint Requirements Oversight Council has endorsed this approach.

The JSF's approved acquisition strategy provides for the introduction of an alternate engine during Lot 5 of the production phase, the first high rate production lot. OSD is considering several alternative implementation plans which would accelerate this baseline effort.

Program Status: The focus of the program is producing effectiveness at an affordable price—the Air Force's unit flyaway cost objective is \$28 million (FY94\$). This unit recurring flyaway cost is down from a projected, business as usual, cost of \$36 million. The Concept Demonstration Phase (CDP) was initiated in November 1996 with the selection of Boeing and Lockheed Martin. Both contractors are: (1) designing and building their concept demonstration aircraft, (2) performing unique ground demonstrations, (3) developing their weapon systems concepts. First operational aircraft delivery is planned for FY08.

APPENDIX H

AIRCRAFT RESEARCH DATA: RAH-66 COMANCHE

All references to quantitative and qualitative aircraft data in this appendix are from the Federation of American Scientists website unless otherwise noted with an appropriate parenthetical reference.

The Boeing-Sikorsky RAH-66 Comanche is the Army's next generation armed reconnaissance helicopter. It also is the first helicopter developed specifically for this role. The Comanche will provide Army Aviation the opportunity to move into the 21st century with a weapon system of unsurpassed warfighting capabilities crucial to the Army's future strategic vision. The Comanche is intended to replace the current fleet of AH-1 and OH-58 helicopters in all air cavalry troops and light division attack helicopter battalions, and supplement the AH-64 Apache in heavy division/corps attack helicopter battalions.

The first Boeing-Sikorsky RAH-66 Comanche prototype was rolled-out at Sikorsky Aircraft, Stratford, Connecticut, May 25, 1995. The prototype's first flight was made on 04 January 1996. The second prototype is scheduled to fly in late March 1999. Six early operational capability aircraft are scheduled to be delivered 2002 to participate in an Army field exercise in 2002-2003, or possibly later in "Corps 04". The Comanche is powered by two Light Helicopter Turbine Engine Co. (LHTEC) T800-801 engines. These advanced engines and a streamlined airframe will enable the Comanche to fly significantly faster than the larger AH-64 Apache.

The RAH-66 Comanche helicopter's primary role will be to seek out enemy forces and designate targets for the AH-64 Apache Attack helicopter at night, in adverse weather, and in battlefield obscurants, using advanced infrared sensors. The helmet has FLIR images and overlaid symbology that can be used as a heads up display in nape-of-the-earth (NOE) flight.

The aircraft has been designed to emit a low-radar signature (stealth features). The Comanche will perform the attack mission itself for the Army's light divisions. The RAH-66 will be used as a scout and attack helicopter to include an air-to-ground and air-to-air combat capability. The Comanche is slated to replace the AH-1 Series Cobra light attack helicopter, the OH-6A Cayuse, and the OH-58A/OH-58C Kiowa light observation helicopters.

The Comanche mission equipment package consists of a turret-mounted cannon, night-vision pilotage system, helmet-mounted display, electro-optical target acquisition and designation system, aided target recognition, and integrated communication/navigation/identification avionics system. Targeting includes a second generation forward-looking infrared (FLIR) sensor, a low-light-level television, a laser range finder

and designator, and the Apache Longbow millimeter wave radar system. Digital sensors, computers and software will enable the aircraft to track and recognize adversaries long before they are aware of the Comanche's presence, a key advantage in both the reconnaissance and attack roles.

Aided target detection and classification software will automatically scan the battlefield, identifying and prioritizing targets. The target acquisition and communications system will allow burst transmissions of data to other aircraft and command and control systems. Digital communications links will enable the crew unparalleled situational awareness, making the Comanche an integral component of the digital battlefield.

The armament subsystems consist of the XM301 20mm cannon, and up to 14 Hellfire anti-tank missiles, 28 Air-to-Air Stinger (ATAS) anti-aircraft missiles, or 56 2.75 inch Hydra 70 air-to-ground rockets carried internally and externally. Up to four Hellfire and two Air-to-Air Stinger (ATAS) missiles can be stowed in fully-retractable weapons bays and the gun can be rotated to a stowed position when not in use. This design feature reduces both drag and radar signature.

Mission management, status, and control information is provided over the MIL-STD-1553B databus between the mission equipment packages and the Turreted Gun System. The Comanche will have enhanced maintainability through its modular electronics architecture and built-in diagnostics.

APPENDIX I

AIRCRAFT RESEARCH DATA: V-22 OSPREY

All references to quantitative and qualitative aircraft data in this appendix are from the Federation of American Scientists website unless otherwise noted with an appropriate parenthetical reference.

The V-22 Osprey is a tiltrotor vertical/short takeoff and landing (VSTOL), multi-mission air-craft developed to fill multi-Service combat operational requirements. The MV-22 will replace the current Marine Corps assault helicopters in the medium lift category (CH-46E and CH-53D), contributing to the dominant maneuver of the Marine landing force, as well as supporting focused logistics in the days following commencement of an amphibious operation. The Air Force variant, the CV-22, will replace the MH-53J and MH-60G and augment the MC-130 fleet in the USSOCOM Special Operations mission. The Air Force requires the CV-22 to provide a long-range VTOL insertion and extraction capability. The tiltrotor design combines the vertical flight capabilities of a helicopter with the speed and range of a turboprop airplane and permits aerial refueling and world-wide self deployment.

Two 6150 shaft horsepower turboshaft engines each drive a 38 ft diameter, 3-bladed proprotor. The proprotors are connected to each other by interconnect shafting which maintains proprotor synchronization and provides single engine power to both proprotors in the event of an engine failure. The engines and flight controls are controlled by a triply redundant digital fly-by-wire system.

The airframe is constructed primarily of graphite-reinforced epoxy composite material. The composite structure will provide improved strength to weight ratio, corrosion resistance, and damage tolerance compared to typical metal construction. Battle damage tolerance is built into the aircraft by means of composite construction and redundant and separated flight control, electrical, and hydraulic systems. An integrated electronic warfare defensive suite including a radar warning receiver, a missile warning set, and a countermeasures dispensing system, will be installed.

Background Info: The V-22 is being developed to meet the provisions of the April 1995 Joint Multi-Mission Vertical Lift Aircraft (JMVX) Operational Requirements Document (ORD) for an advanced vertical lift aircraft. The JMVX ORD calls for an aircraft that would provide the Marine Corps and Air Force the ability to conduct assault support and long-range, high-speed missions requiring vertical takeoff and landing capabilities.

Since entry into FSD in 1986, the V-22 T&E program has concentrated principally on engineering and integration testing by the contractors. Three periods of formal development test by Naval Air Warfare Center-Aircraft Division (NAWCAD) Patuxent River, plus OTA participation in integrated test team (ITT) activities at Patuxent

River, have provided some insight into the success of the development effort. After transition to EMD in 1992, an integrated contractor/government test team conducted all tests until OT-IIA in 1994. Since then, two additional periods of OT&E have been conducted. The first operational test period (OT-IIA) was performed by COMOPTEVFOR, with assistance from AFOTEC, from May 16 to July 8, 1994, and accomplished 15 hours of actual flight test operations, within an extremely restricted flight envelope. The Navy, with Air Force support, published a joint evaluation report addressing most mission areas the V-22 is to perform.

OT-IIB was conducted from September 9, to October 18, 1995, and comprised 10 flight hours in 18 OT&E flights, plus ground evaluations. A joint Air Force/Navy OT-IIB report was published. Partly in response to DOT&E concern expressed over the severity of V-22 downwash in a hover observed during OT-IIA, the Navy conducted a limited downwash assessment concurrently with OT-IIB, from July to October 1995.

Test & Evaluation Activity: In accordance with the approved TEMP, OT-IIC was conducted in six phases at NAS Patuxent River and Bell-Boeing facilities in Pennsylvania and Texas, from October 1996, through May 1997. Significant flight limitations were placed on the FSD V-22 in OT&E to date, including:

- not cleared to hover over unprepared landing zones until OT-IIC
- no operational internal or external loads or passengers
- moderate gross weights only
- not cleared to hover over water.

In addition, FSD aircraft equipment was not representative of any mission configuration. Together, these aircraft clearance and configuration limits produced an extremely artificial test environment for OT-IIC. The OT-IIB report expressed serious concerns regarding the potential downwash effects, and recommended further investigation. While a limited assessment of downwash and workaround procedures was included in OT-IIC, complete resolution of the downwash issue will not be possible until the completion of OPEVAL, just prior to milestone III in 1999.

The Navy is conducting an aggressive LFT&E program on representative V-22 components and assemblies, in compliance with a DOT&E-approved alternative LFT&E plan. The V-22 program was granted a waiver from full-up, system-level LFT&E in April, 1997. The vulnerability testing that the program is performing is appropriate and will result in the improvement of aircraft survivability. The V-22 program TEMP was last approved by DOT&E on September 28, 1995, and will be updated prior to each OT&E period scheduled.

Test & Evaluation Assessment: With DOT&E encouragement, the Navy greatly expanded the scope of OT-IIC to get better insight into the effectiveness and suitability of the EMD design. The results, while not yet conclusive regarding the potential operational effectiveness and suitability of operational aircraft, were encouraging. The six phases of

the OT-IIC Assessment included: (1) shipboard assessment, (2) maintenance demonstrations, (3) tactical aircraft employment via FSD aircraft and manned flight simulator, (4) operational training plans, (5) program documentation review, and (6) software analysis.

In assessing the operational effectiveness and suitability COIs, COMOPTEVFOR and AFOTEC found that in most cases, only moderate risk exists that the COIs will not be satisfactorily resolved when development is complete. Enhancing features observed during OT-IIC included aircraft payload, range and speed characteristics better than the stated operational requirements. In addition, reliability, availability and maintainability of the EMD aircraft appeared to be significantly improved over those of the FSD aircraft.

Several areas of concern first discovered in OT-IIA or OT-IIB remain unresolved because of limitations to the EMD flight test operations. These concerns include severe proprotor downwash effects during personnel insertion and extraction via hoist or rope. In addition, concerns exist in the areas of communications, navigation, and crew field of view. New concerns arising from OT-IIC regarding the EMD schedule are being addressed by the program manager. Also, the reliability and maintainability of a few subsystems will require management attention. Despite these concerns, the V-22 design remains potentially operationally effective and suitable.

The aircraft's prime contractors include Boeing Company's helicopter division in Ridley Park, PA, and Bell Helicopter Textron of Fort Worth TX. In 1986 the cost of a single V-22 was estimated at \$24 million, with 923 aircraft to be built. In 1989 the Bush administration cancelled the project, at which time the unit cost was estimated at \$35 million, with 602 aircraft. The V-22 question caused friction between Secretary of Defense Richard B. Cheney and Congress throughout his tenure. DOD spent some of the money Congress appropriated to develop the aircraft, but congressional sources accused Cheney, who continued to oppose the Osprey, of violating the law by not moving ahead as Congress had directed. Cheney argued that building and testing the prototype Osprey would cost more than the amount appropriated. In the spring of 1992 several congressional supporters of the V-22 threatened to take Cheney to court over the issue. A little later, in the face of suggestions from congressional Republicans that Cheney's opposition to the Osprey was hurting President Bush's reelection campaign, especially in Texas and Pennsylvania where the aircraft would be built, Cheney relented and suggested spending \$1.5 billion in fiscal years 1992 and 1993 to develop it. He made clear that he personally still opposed the Osprey and favored a less costly alternative.

The program was revived by the incoming Clinton administration, and current plans call for building 458 Ospreys for \$37.3 billion, or more than \$80 million apiece, with the Marines receiving 360 Ospreys, the Navy 48 and the Air Force 50. The first prototype flew in 1989. As of early 2000 three test aircraft had crashed: no one was killed in the 1991 crash, an accident in 1992 killed seven men, and the third in April 2000 killed 19 Marines.

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